JPRS-JST-86-019

16 JULY 1986

Japan Report

SCIENCE AND TECHNOLOGY

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JAPAN REPORT

SCIENCE AND TECHNOLOGY

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BIOTECHNOLOGY

DEVELOPMENT OF BIOCYBERNETICS DISCUSSED

Tokyo BIO INDUSTRY in Japanese Mar 86 pp 49-55

[Article by Kunihiko Fukushima, Chief investigator, NHK Broadcasting Technical Research Laboratory]

[Text] The brain of a living organism demonstrates a highly advanced information processing ability not realizable by today's computers. Biocybernetics research is attracting attention as it probes into that mechanism using a neural network model as the medium in an attempt to discover design principles for new information processing systems. I shall introduce the current state of research by citing several research achievements.

1. Introduction

The brain of a living organism has a highly advanced information processing ability unmatched by the most advanced information processing systems including computers. Consequently, if we elucidate the mechanism of information processing which occurs in the brain, it should lead immediately to the development of a high performance information processing system.

The traditional means used to study brain function include physiology and psychology. In physiology, for example, a microelectrode of less than 1 micrometer in diameter is inserted into the brain of an experimental animal and electrical signals are observed as the response of the neurons touching the tip of the electrode to study the configuration of the neural network of the brain. On the other hand, in psychology, the brain as a whole is regarded as a black box and attempts are made to elucidate brain mechanisms through its input/output relationships. As a result of these studies, the elucidation of brain mechanisms progressed steadily, and new revelations are being made in rapid succession.

However, there is an enormous number of neurons in the brain, which are complexly connected to constitute one large neural network. The number of neurons in the brain is said to be as many as 10 billion or more in humans. Consequently, although today's neurophysiological technique of analyzing the responses of a single neuron using a microelectrode or the psychological technique of observing the whole brain as a black box may provide a great deal of fragmentary knowledge,

it is nearly impossible using these methods alone to understand the neural network of the brain in its entirety.

Therefore, the importance of a new research technique different from the conventional method, i.e., biocybernetics, has been attracting attention. Biocybernetics research begins with the construction of a neural network model showing the same responses as the brain regarding the functions to be studied. In building the model, the facts elucidated by physiological or psychological experiments are incorporated as faithfully as possible, but the unsolved parts are introduced as a rough hypothesis. The characteristics of the model constructed in this manner are examined by computer simulation or mathematical analyses. If, the model shows responses different from that of the brain, an error in the hypothesis used is inferred and, it is corrected. The mechanism of the brain is pursued by repeating such sequences many times.

In other words, cybernetics research uses a technique from the standpoint of synthesis whereas the goal of conventional physiology and psychology has been elucidation of the brain from the analytical standpoint. The relationship between cybernetics and conventional physiological and psychological research is the same as the relationship between theoretical physics and experimental physics.

Once a model is finished, the neural network of the brain is simplified and abstracted in the form of a model whereby it becomes readily identifiable as to which mechanism is playing an essential role for information processing in the brain. Moreover, the algorithm of the neural network is usually described in a form that can be run directly as a computer program. Therefore, the construction of a neural network model is not only useful for the development of brain research but also leads to the develòpment of design principles for new information processing systems that directly incorporate the advantages of the nervous system. In other words, biocybernetics research is the most direct means to tie research achievements in physiology and psychology to engineering applications.

Neural network models can be hardware such as an electronic circuit or mechanical system, etc. or software that describes the action with mathematical formulae and simulates it with a computer. Most of the recently published models are of the latter type. In this article, trends in biocybernetics research is reviewed by introducing representative selections of mainly the studies by the author's group.

2. Model for visual sensory system

It has long been known that in cats or monkeys the ganglion cells that transmit signals from the retina have a mostly-on or mostly-off type circular receptive field and function by detecting the contrast in the pattern of stimuli received by the retina. Many attempts[1),3)] have been made to model this function using a linear or nonlinear spatial network. A representative model is a bilayer neural network model having a uniform structure with the first layer corresponding to the visual cell layer (input layer) sensitive to light, and the second layer corresponding to the cells transmitting the output from the retina, i.e., the ganglion cell layer, where the focus was only the input-output relationship between the two layers. For the cells of the second layer, analog threshold elements are used,

proving that such circuits demonstrate contrast detection capabilities and enhance edge effects in a diagram, or function to diminish shadings (gradual irregularities in brightness) contained in a diagram or its background[4].

The visual information from the retina is relayed to a place called the lateral geniculate body and subsequently to the area called the visual field at the back of the cerebrum. It is known that the visual field contains cells that respond to linear components or edges with specific inclinations as well as cells that respond to various characteristics contained in the stimulus pattern projected on the retina.

Hubel and Wiesel classified the cells in the visual fields of the cerebrum into simple form cells, complex form cells, very complex form cells, etc. based on the character of the receptive field and hypothesized that they constitute a hierarchical neural network. Many neural network models have been published based on this hierarchy hypothesis[1]. For example, the multilayer network model[4] assembled with analog threshold elements has the ability to extract the curvatures of various parts of curvelinear graphs.

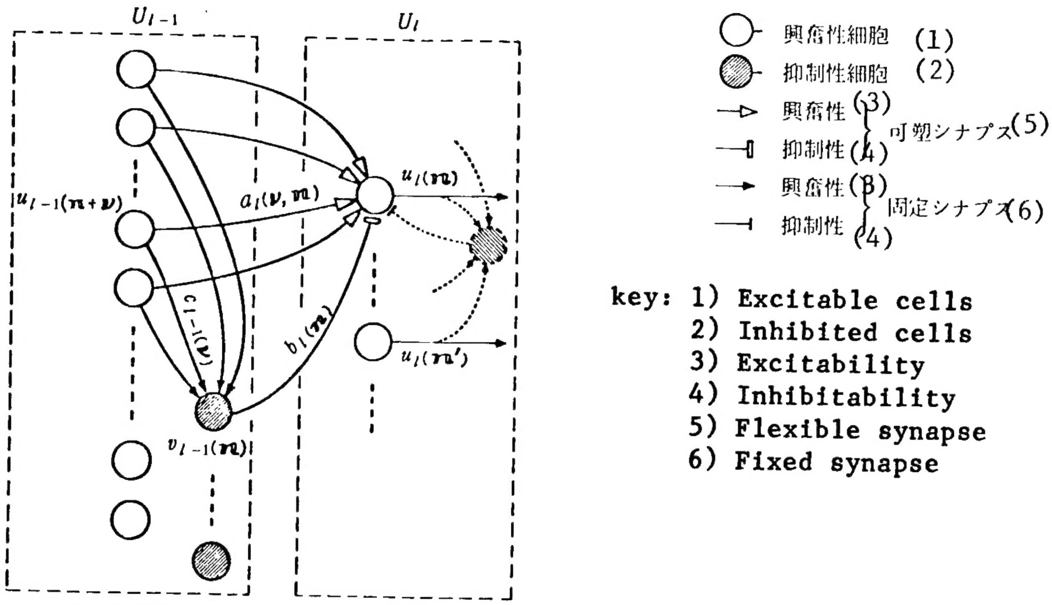
Many such models have been built focusing on cellular function for extracting various characteristics in the visual field. They were built with a macroscopic view of the approximate information flow in the visual field rather than modeling the detailed responses of individual cells in the brain.

However, when neural connections in the visual field are examined in detail, several experimental facts emerge which do not always agree the Hubel-Wiesel hierarchical hypothesis. Therefore, attempts are being made in various places[1,3] to construct accurate neural network models with a microscopic view of the individual cellular functions in the visual field and the state of their connection based on such new knowledge. However, these models are all in the working hypothesis stage and the true state of the neural network in the visual field is not yet well understood.

At any rate, these modeling concepts regarding the visual sensory system will provide major clues in designing the pretreatment and characteristics extraction networks in image processing and pattern recognition.

3. Model for self-organizing processes

The neural network of the brain is not fully formed at the birth of an organism, but it gradually grows through experience and learning after birth to adapt to the environment in which it is placed. Such a phenomenon is called the self-organizing process of the neural network. However, the mechanism by which self-organization proceeds has not much yet been elucidated even in physiology. It is believed that external stimuli affect the formation of new synapses between neurons or change the strength of existing synaptic connections. However, for the present, the cause and effect relationships between neurons and stimuli are not well understood. Various hypotheses have been proposed regarding these plastic synapses, and many experiments have been conducted to prove the hypotheses. However, no hypothesis has been fully proven. In research involving self-



key: 1) Excitable cells
2) Inhibited cells
3) Excitability
4) Inhibitability
5) Flexible synapse
6) Fixed synapse

Fig. 1 Cognitron configuration

Shows intercellular connections between two adjacent layers.

The law asserting that only cells which transmit a maximum output are subjected to reinforcement of the input synapses is useful in preventing a redundant network formation in the self-organizing process. In other words, only those cells responding most strongly to certain stimulus patterns (or partial characteristics of that pattern) are selected and will grow as the cells responding selectively to that pattern. Since only the maximum output cells are selected and reinforced, those cells responding to the same patterns or characteristics are not duplicated. Consequently, an efficient self-organizing process is possible "without a teacher" even for a multi-layer network.

If we assume that synaptic connections change according to such a hypothesis, even when certain cells are injured, other cells serve as substitutes, i.e., a self-repair action results. In other words, when cells that were strongly responding to a certain stimulus are somehow damaged and cease to respond, among nearby cells whose reinforcement of the input synapse have been inhibited, those cells that happen to respond more strongly than others to that stimulus grow to serve as a substitute for the damaged cells.

In addition, Cognitron assumes that the maximum value detection hypothesis holds not only for excitable flexible synapses, but also for inhibited flexible synapses. The fact that inhibited synapses are reinforced along with excitable synapses plays an important role in improving the ability of the cells to respond selectively to only a specific characteristic alone, i.e., the pattern separation ability.

4. Pattern recognition and Neocognitron

The above-mentioned Cognitron is only for repeated displays of several kinds of stimulus patterns, and cells selectively responding to a specific stimulus pattern are formed in the network and nurtured in their ability to recognize the stimulus pattern. However, in the case of Cognitron, even for a pattern which has been already learned, if that pattern is displayed at a different position from the learned one, or if the size or shape of the pattern is altered, it is judged as a display of an entirely different pattern. Fukushima proposed Neocognitron[7)], a neural network model without these shortcomings. Neocognitron is not affected by the shifts in the display position of the stimulus pattern or slight distortions and has the ability to correctly recognize patterns based upon similarities in the forms.

Neocognitron is a multi-layer neural network having the configuration shown in Fig. 2. U_0 is an input layer with arranged photoreceptors. U_s is a layer of cells named S cells, and the input connection of the S cells is reinforced according to the maximum value detection hypothesis as in the case of Cognitron. However, in the case of Neocognitron, another hypothesis is added, which assumes that a maximum output cell not only strengthens the intensity of the input connection to itself but influences input connections to a group of cells surrounding it. As a result, other cells surrounding the maximum output cell and receiving information from another position in the input layer are also reinforced to have a receptive field with the same properties as the maximum output cell. Consequently, even if the learned stimulus pattern is applied at a different position on the input layer, one of the group of cells would detect the stimulus pattern and respond.

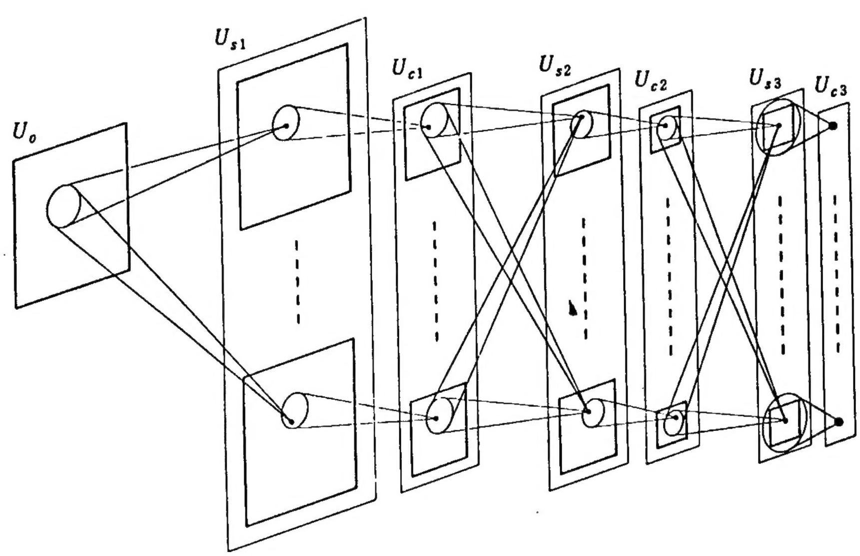


Fig. 2 Configuration of Neocognitron

Another point in which Neocognitron differs from Cognitron is that C cell layers, U_c, are inserted behind each S cell layer having flexible input synaptic

When the network structure prior to adding the feedback path was an autorecollection type, the addition of feedback path allows realization of a network with functions such as eliminating the noise contained in the input stimulus, or when an unclear stimulus pattern resembling two overlapped patterns occurs, selecting either one of the patterns[2),3)].

By hearing only a bar of a melody we have heard before, we can recollect the melody that follows. Fukushima[10)] added a feedback path with a time delay to a cross-recollection type associative memory network of correlation matrix type and produced a network that associates a series of patterns that changes with time.

The above models have a configuration in which mainly the final recollection output alone of the associative memory network is fed back to the input side. However, a higher degree of information processing becomes possible when each layer of the hierarchical network is configured to transmit the feedback signals to the previous layer. For example, when the cells in each layer of a Cognitron type multi-layer network are designed to form an efferent (i.e., descending) connection, which pairs the afferent (i.e., ascending) connection, to cells in the previous layer, a model equipped with both associative ability and pattern recognition ability (hierarchical associative memory model) can be produced[11)]. When this network is exposed to a multiple number of learning patterns, allowed to self-organize, and two to three of the patterns used for learning are overlapped and provided as the stimulus input of an ambiguous pattern, the associative output layer produces a sequential readout of the overlapped learning patterns one at a time. At the same time, in the cell layer where pattern recognition results appear, an output occurs from cells corresponding to the category manifested in the associative output layer at that time.

By further developing this model from a Cognitron type to a Neocognitron type, models that are not affected by stimulus pattern distortion or position shifts and are capable of pattern segmentation, association, recognition, etc. have been built[12)].

6. Conclusions

Biocybernetics research that attempts to elucidate the information processing mechanism of the brain using neural network models as a tool is gradually taking hold as one of the important schools for new techniques in brain research. In particular, it is expected to provide a major clue for research on higher order centers where physiological experiments are difficult. In addition, from the engineering point of view, it is the most direct method to incorporate a superior algorithm for information processing by the brain into a new systems design. I hope this article helped readers to better understand the significance and the current state of biocybernetics research and stimulate more researchers to enter the research field.

In this article, although I have introduced mainly models closely related to visual information processing and pattern recognition mechanisms, I would like to add that there are many neural network models available concerning auditory and motor systems as well.

organizing mechanisms including learning and memory, what sort of plastic synapse characteristics need be present in order to construct a neural network model that demonstrates the same responses as the brain? Biocybernetics research that examines the justifiability of flexible synapse hypotheses from this contrary viewpoint has become a particularly powerful research tool.

Pattern recognition research in engineering often classifies the learning process into "learning with a teacher" and "learning without a teacher." In the case of learning with a teacher, every time a pattern to be learned is displayed in a neural network (or pattern recognition system), the classification category of the pattern is also taught. Or, every time a pattern is displayed, have the neural network identify the pattern after which the neural network is advised of the accuracy of the answer. The neural network proceeds with a self-organizing process by using the information imparted by the external "teacher."

On the other hand, in the case of learning without a teacher, several kinds of patterns to be learned are merely displayed repeatedly to the neural network, and no information whatsoever is provided as to which category the respective patterns are classified into. Influenced by its early state or the form of stimulus patterns provided externally as well as their frequency of occurrence, the neural network self-organizes and, in the process, constructs the standard for pattern classification on its own.

As a model for learning with a teacher, Perceptron[5)] proposed by Rosenblatt around 1957 is well-known, and there are numerous models resulting from that school. At the time Perceptron was presented, great expectations were placed upon its pattern recognition ability, and many studies followed. However, upon careful study, it was revealed that Perceptron merely classifies patterns based on the degree of overlapping of two sets of stimulus patterns on the input layer and does not have the great ability initially expected. However, a learning model with a teacher that greatly surpasses Perceptron has not been found.

Although a few proposals for models of learning without a teacher were made in the early days, it is relatively recent that those having high information processing capabilities began to be published.

Cognitron[6)] proposed by Fukushima is a multilayer neural network model having self-organizing functions, in which the cells that selectively respond to patterns displayed frequently in the learning steps are formed within the network by learning without a teacher. Cognitron has a configuration of several cell layers with cascade connections as shown in Fig. 1. The cells within a network having flexible input synaptic connections are reinforced according to the "maximum value detection hypothesis," which asserts that "as long as there are no other cells nearby with a greater output (i.e., when the self has the maximum output in a subregion that includes itself), only those input synapses receiving non-zero signals are subject to reinforcement proportional to the intensity of the input signals."

connections. Each C cell receives excitable synaptic connections from another group of S cells having receptive field with the same characteristics, and should any one of the S cells in the group output, C cells are also designed to output. Since the positions of the group of S cells on the input side of a single C cell vary slightly from each other in the receptive field, the C cell responds to the same characteristics as the S cells on the input side but is not influenced as much as S cells by a position shift in the characteristics.

As explained, by adding C cell layers behind the S cell layers, Neocognitron is designed to allow intercharacteristic position shifts a little at a time in the extraction and integration processes of the characteristics in each step of the multi-layer network. The manipulation of allowing a slight position shift to cope with the final large position shift is very useful in executing a strong pattern recognition not only of the input pattern position shifts but also of distortions.

It has been proven[8)] by detailed computer simulation that the Neocognitron concept is effective not only as a brain model but also as a principle for designing a character or figure recognition system. For example, in the case of handwritten numerals between 0 and 9, it allows even microcomputers to realize a system that correctly recognize patterns with considerable distortion. For example, in the case of the program produced by the author's group for a microcomputer (NEC PC-9801m), the time required for recognition of 1 character is about 8-30 seconds. The fact that recognition is possible at these speeds even with a microcomputer demonstrates pattern recognition feasibility at a sufficiently usable speed and accuracy even without a large-scale system if special-purpose hardware is built.

5. Associative memory and éfferent connection

As we consider the process of information processing in the brain, information does not always flow in one direction from the periphery to the center. In the case of seeing an unclear, ambiguous pattern, the procedure would be first to mobilize intuition to assess what the pattern is likely to be, followed by a confirmation of whether or not initial intuition is correct. Or, we frequently experience a state in which a certain pattern is provided that causes us to associate it with other patterns sequentially. In focusing on such a phenomenon in the brain, one must consider a model that takes into account not only a hierarchical information flow toward the center from the periphery, but also a feedback type (i.e., top-down type) of information flow directed from the center to the periphery or a chain reaction produced between cells in the same layer, etc.

A correlation matrix[9)] as well as many other models [2),3)] have been devised as models for associative memory. For example, let us add a path that feeds back the recollection output to the input side of an associative memory model of the correlation matrix type. In such a network, the output recalled by a certain stimulus functions as the input stimulus at the next step. Consequently, once a stimulus is provided, the response of the neural network is sustained for a long time even if the input stimulus is subsequently removed. In this situation, the response pattern, i.e., the recollection output, gradually changes with time.

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BIOTECHNOLOGY

NEW DEVELOPMENTS IN BIOMASS TECHNOLOGY DESCRIBED

Tokyo BIO INDUSTRY in Japanese Jan 86 pp 44-51

[Article by Osamu Yamakawa, Ministry of Agriculture, Forestry and Fisheries, Vegetable Research Center, Kurume Division, Seed Development Laboratory No 2]

[Text] Special Report on Agribusiness Developments

New Developments in Biomass Technology

Biomass resources, reproducible resources that have been the focus of much attention recently, are broadly classified as plant resources or unutilized resources. This article discusses the basic research to improve the physical productivity of plants, particularly those which are cultivated as plant resources, and the status and future of typical research in biomass plants in Japan, which is the basis of the Ministry of Agriculture and Marine Resources' "Green Energy Plan" and "Biomass Conversion Plan."

1. Introduction

"Biomass," a word long used in ecology, is translated in Japanese as "living new materials." Although biomass is generally thought of as a substitute for petroleum, it actually has broader applications than energy--live organisms for things like food, animal feed, and industrial raw materials, for example (Figure 1 [omitted]). On top of this, biomass is now also used to refer to solar energy converted by plant photosynthesis and stored as organic matter. Thus, biomass resoures differ from coal or oil in being reproducible at the same time as being dispersed worldwide.

According to Suru, biomass resources fall into two general categories, plant resources and unutilized resources. As shown in Table 1, "cultivated plant resources" refers either to the development of new plants to produce large amounts of useful material or the conversion of already existing plants to do so, and "unutilized" to using leftover and waste products generated by processing and producing living things.

The Ministry of Agriculture, Forestry and Fisheries has established two large-scale projects, the "Green Energy Plan" (1978-1987) and the "Biomass

Table 1. Types of Biomass Resources

Biomass Resources	Cultivated Plant Resources	Farmland Resources	Starch crops...sweet potato*, white potato
			Sugar crops...sugar cane, sweet sourghum*, sugar beet
			Oil & fat crops...sunflower*, rapeseed*
			Fiber crops...kenaf*, jute*
			High-growth plants...mallow*, grain amaranthus*
		Forest Resources	Oil plants...eucalyptus*, blue coral
			High-growth plants...poplar, white birch*
		Marine Resources	High-growth plants...giant kelp*, red kelp*
			Algae...chlorella, <u>supirurina</u>
	Unutilized Resources	Agricultural Resources	Farming waste...rice straw, rice hulls, fruit tree prunings
			Agricultural processing waste...fruit juice sediment, starch sediment, <u>bagasu</u>
		Livestock Resources	Barnyard waste...excrement, urine
			Livestock processing waste...blood, bones, viscera, boiled stock
		Aquatic Resources	Fishing boat waste...rejected fish
			Fish processing waste...boiled stock, fish entrails, fish bones
		Forestry Resources	Unutilized and underutilized plants...Jap. beech, Jap. oak, bamboo grass*, bamboo
			Woodland brush...twigs, leaves
			Lumber processing waste...sawdust, bark, wood scraps

Note: An asterisk(*) indicates item is included in the Ministry of Agriculture and Marine Resources large-scale project, "Biomass Conversion Plan" (1981-1990).

Conversion Plan" (1981-1990), and is now promoting experimental research on the efficient conversion and use of organic matter and rapid improvement of plant productivity.

The subjects I would like to discuss here are the current status of and future prospects for biomass research in these projects.

2. Basic Research in Improving Physical Productivity

The first consideration in cultivating plants for biomass resources is the cost of the plant itself. Unless it is cheap it cannot be used as raw material for conversion and use. Fast, practical methods improve physical productivity (yield) which lower costs.

Basic research is being done in the "Green Energy Plan" first to try to raise physical productivity, which means to improve photosynthetic products.

2.1 Improving Photosynthetic Capacity

Plants use sunlight to synthesize organic matter from carbonate gas, but the efficiency of using that energy is said to be 2 percent at most, which is quite low. C_3 plants (plants which produce C_3 compound phospho-glycerine first at the time of carbonate gas fixation in photosynthesis), which include many crops like rice, soybeans, and beets, are less efficient than C_4 plants (plants which similarly generate C_4 compound apple acid or asparagus acid) such as corn or pearl millet (Table 2).

The reasons for this are that C_3 plants do not have structures like the concentrated carbonate gas in C_4 plants to carry out photosynthesis efficiently, and that they absorb light, causing energy loss during photosynthesis. Research as shown in Figure 2 is therefore needed to improve the photosynthetic function of C_3 plants. [Figure 2 omitted]

To make a C_3 plant into a C_4 plant, a C_4 type was first crossed with a C_3 type of the same genus (orache), producing a hybrid breed up to the F_3 generation and one crossed back with a C_4 type. These breeds are now being analyzed for enzymes in C_4 photosynthesis and carbonate gas compensation points. Research on C_4 plant conversion is also being done using genetic engineering techniques, such as isolating and refining enzymes in C_4 photosynthesis, determining the amino acid configuration, and developing methods of detecting genomic DNA.

A breed of barley which appeared to be a variant with damaged photo-absorption was obtained by treatment with ethylmethyl sulfanate to control the photo-absorption of C_3 plants. Photo-absorption inhibitors such as amino acetonitrile and amino methane sulfanate are also being developed.

Work is also being done on the leaf aging, the field of research which until now has been farthest behind, using new methods like light and sound and new materials like slow-aging brown leaves.

Table 2. Comparison of Characteristics of C_3 and C_4 Plants

FEATURE	C_3 PLANTS	C_4 PLANTS
1. CO_2 fixing system	Calvin's cycle (compounds which release 3 carbon molecules first in photosynthesis)	G-carbonic acid cycle (makes compounds whose first product is 4 carbonic acid molecules)
2. Photosynthetic capacity	15–40mg (CO_2mg/100cm^2/h)	35–80mg (CO_2mg/100cm^2/h)
3. CO_2 compensation point, saturation density	21–150ppm (high density)	0–15ppm (low density)
4. Light absorption	yes	almost none
5. Photosynthesis in low O_2 density accelerated	yes	no
6. Leaf structure	vascular bundle sheath is small; leaf flesh, except for leaf margin, is dispersed type.	vascular bundle sheath is large; leaf flesh, including leaf margin, is dense type.
7. Light saturation in photosynthesis	yes	no
8. Optimum temp. for photosynthesis	low-high (18–23°C)	high (28–33°C)
9. Optimum temp. for growth	low-high (15–22°C)	high (25–35°C)
10. Minimum temp. for growth	low (5°C)	high (10°C)
11. Stored carbohydrates	fructose	non-fructose (starch, sucrose)
12. Amount of water needed	a lot (682g/gDM ...average of 10 types	a little (301g/gDM ...average 29)
13. Daylight response	long day	medium-long day, also short day
14. Climate type	cold climate type	mild climate type
15. Grass types (examples)	rice, barley, orchard grass, Italian rye grass, cattails, etc.	sugar cane, corn, rose grass, Dallis grass, etc.

Table 3 shows prospects for future developments in technology to improve the photosynthetic capacity of C_3 plants.

2.2 Improving the Translocation and Storage Capacity of Photosynthetic Production

The purpose of improving the translocation and storage capacity is not simply to raise the yield of the harvest desired, like fruit or seeds, but is also

Table 3. Progress of Development of Technology To Improve Photosynthetic Capacity of C_3 Plants

Period	Technological Developments			
	(1) Improvement of photosynthetic capacity of C_3 plants	(2) Control of light absorption	(3) Introduction of photosynthesis function to C_4 plants.	(4) Slowing of aging process
1980's	development of varieties that take in large amount of CO_2 by increasing number of pores	•development and utilization of light absorption inhibitor •development of C_3 plants that do not absorb light	-----	-----
1990's	-----	-----	•understanding of biochemical structure of C_4 type photosynthesis •cloning of C_4 type photosynthesis genes	•understanding of biochemical structure of leaf aging •the leaf
21st c.	-----	-----	development of C_3 plant with C_4 type functions by means of genetic engineering	development and utilization of leaf aging inhibitor

necessary to maintain a high level of photosynthetic capacity. This means that even though you have raised the leaf's photosynthetic capacity, it decreases unless you increase the capacity of the sink or the vascular bundle system that accompanies translocation. To improve the translocation and storage capacity of photosynthetic production, research as shown in Figure 3 is needed.

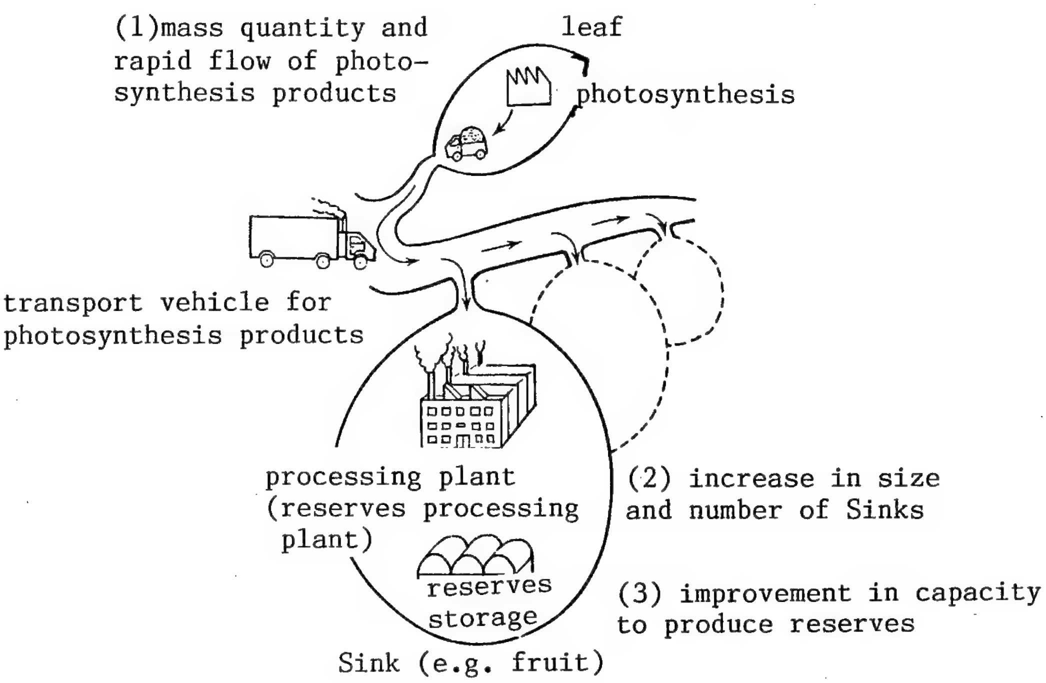

Figure 3. Technological Improvements in Translocation and Storage Capacity in Photosynthesis

The minute structures of the leaf and seed were first studied under an electron microscope in order to understand the route of translocation and storage. The importance of the presence of three types of organelle forms in the phloem cell of the rice kernel and the important role played by "pools" between and among the endosperm and nucellar protuberances when rice and barley translocate to the endosperm was recognized.

Improving the sink's storage capacity was understood by the role played by material containing two types of glycoside different from plant hormones known until now in the form of the tuberous potato root and the role cytokinin in increasing the fleshiness of the sweet potato and of avidin in increasing the ripening rate and granular weight of rice.

Figure 4 shows the prospects for development of advanced technology to improve the translocation and storage capacity of photosynthetic production.

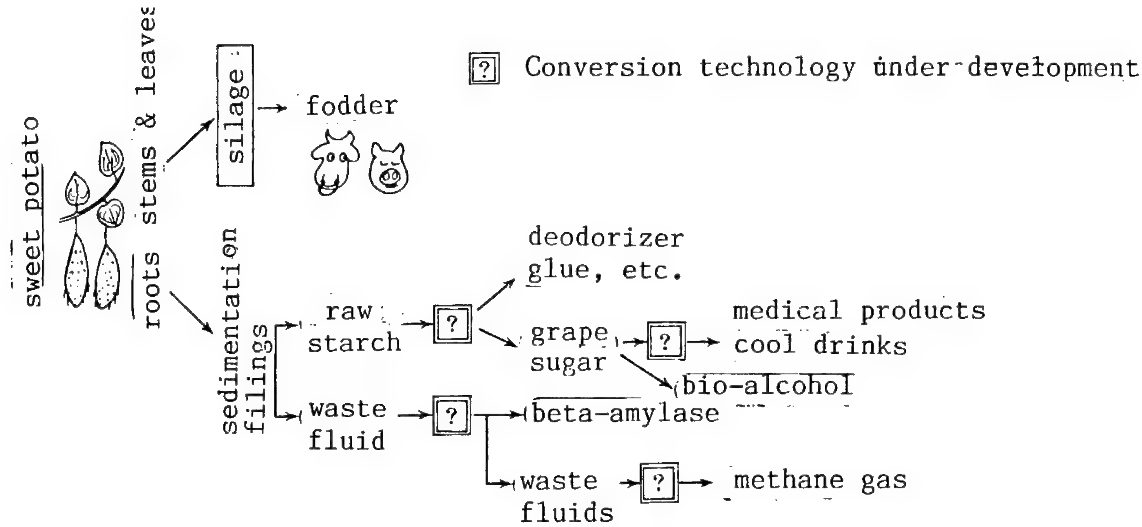

Figure 4. System for Complete Use of Sweet Potato

3. Research in Cultivated Biomass Resource Plants

The objective of the "Biomass Conversion Plan" is to introduce quantitatively and qualitatively useful plants not only to land that is already cultivated, but also to unused lands like marshes and swamps that until now have not been productive, to cultivate them while preserving their ecological balance, and to establish new systems for effectively using them completely. For that reason it is working first on searching for, introducing, and evaluating the characteristics of new plants, and on establishing techniques for multiple crop cultivation, selecting breeds, and developing the technology for their conversion and use.

3.1 New Wet Crops

Crops rarely planted in Japan such as kenaf, jute, and amaranthum were studied for moisture resistance and drying ability with the idea of exploiting unused land like swamps. In order of moisture resistance they were ranked as follows: millet, adlai, kenaf, jute, soybean, sorghum, and amaranthum. Of these, kenaf dried to 13 tons/hectare, 1 ton/hectare of it seeds, making it particularly promising as a new swamp crop. As shown in Table 5, it has seeds that are rich in proteins and fats, and moreover is high in quality because 50 percent of the fats are lineolic acid. Kenaf is a 1-year old Malvaceae herb indigenous to Africa, related to the okra and hibiscus. Its stalk is about 2 meters, with egg-shaped upper leaves and lower leaves with 3-5 fissures. The flower is yellow and resembles that of the hollyhock. Its fiber is white like that of the Japanese linden (lime) and high in quality.

The photosynthesis of zuzania, a wet crop traditionally grown by Indians in North America for food, is also being studied. Its optimum temperature for photosynthesis is about 25°C, but it was found that although that capacity

Table 4. Progress of Development of Technology To Improve the Translocation and Storage Capacity of Photosynthesis Production

	Technological developments		
Period of development	(1) Mass production and rapid translocation in photosynthesis	(2) Increase in size and number of sinks	(3) Improvement in reserve production capacity
1980's	Development of technology to accelerate flow by controlling growth environment, such as temperature	Utilization of technology to accelerate budding using plant hormones	Development of technology to improve reserve production capacity by ordinary cultivation methods, such as fertilizers
1990's	Systematic understanding of course of translocation by physiologically active material	Development and use of physiologically active material to promote pollination	Understanding of biochemical process by which reserves are converted
21st century	Improve course of breeding translocation	--	Development and use of physiologically active material to improve ability to convert reserves

Table 5

(percentage of drying ability)

Name of Product	Protein Content	Fat Content	Ash Content
Adlay	11.0	9.0	2.2
Millet	11.0	5.7	1.8
Sweet sorghum	8.5	3.6	1.7
Amaranthum	14.9	8.0	3.2
Jute	15.1	14.7	8.1
Kenaf	19.8	13.2	5.7

Ministry of Agriculture, Forestry, & Fisheries
Food Product Research Institute (1984 Hirokazu Taira)

drops at temperatures above 30°C, it still retains 80 percent of its maximum capacity even at 17°C. Zuzania can therefore be called a crop suited to cold and temperate regions in Japan, even though it does not dry particularly well.

Because of kenaf's strong moisture resistance, future research will be directed at developing techniques to grow it economically and abundantly in damp areas where it can be introduced. Specific features of cultivating amaranthum, with a weaker moisture resistance but with superior drying ability, and adaptability to poor environments, also need to be understood. It is important to continue the search for and introduction of new crops with superior drying ability and many useful ingredients, regardless of their moisture resistance.

3.2 Sweet Potatoes

Because the sweet potato has a high yield even under poor conditions its importance as a crop came to be appreciated during long famines, but it is now also being watched as an energy crop for production of ethanol.

A comparison of the capacity of different crops in Japan to produce ethanol shows that the sweet potato is high, following just behind sugarcane. The current issue, however, is economic: producing alcohol from crops costs two to three times more than gasoline. Because the cost of raw materials makes up a high proportion of the production cost, establishing techniques for growing the sweet potato cheaply and abundantly and bringing down the cost of raw materials is thought to be a shortcut to making bio-alcohol practical.

To reduce grafting and raising seedlings, which are now the most labor-intensive tasks, work is being done to develop varieties which are receptive to the "seed cultivation method" and whose seeds can be sowed directly.

The yield under this new method of cultivation accounted for about 70 percent of existing graft cultivation. Attempts are being made to obtain the maximum yield by various means such as rapid cultivation, super hardy breeds, multicropping, and growth regulating materials. In 1 year, more than 70 tons/hectare of raw potatoes were raised in Kagoshiima.

Development of the technology for complete conversion and use including alcohol is shown in Figure 4.

3.3 Sweet Sorghum

Sugar millet is another name given to a variety of millet. Its stalk sap is 13-14 percent sugar and is already in use in Brazil and the United States as a major fuel substitute for gasoline. It was introduced to Japan at the beginning of the Meiji period for producing sugar but, because the sugar did not crystallize well, disappeared, and was not later cultivated. Little research has, therefore, been done in Japan, and must start from such basics as introduction of superior varieties from abroad, selection of suitable places for growing them, and understanding the particular features of their cultivation.

Based on the results of experiments to date, "sumac" is believed to be suitable for temperate to cold climates and "theis" for warm climates; their yield (weight of fresh stalks) of 50-60 tons/hectare is about 14-15 percent brick. In particular, a yield of 60 tons/hectare and more than 18 percent bricks was obtained under favorable climactic conditions in Hokkaido in 1983. On the one hand, in Tanegashima, it has an advantage over sugarcane in having a shorter growing time, but neither its yield nor its bricks are as great. Of the varieties introduced recently, "M81E" and "Big Sugar Sorghum" are superior not only in yield but also in moisture resistance, making it necessary now to study their adaptability to particular locales.

Seigawa has offered a comprehensive usage system including bagasse, a sap residue, and Figure 5 shows current developments in the exchange of technology for that purpose.

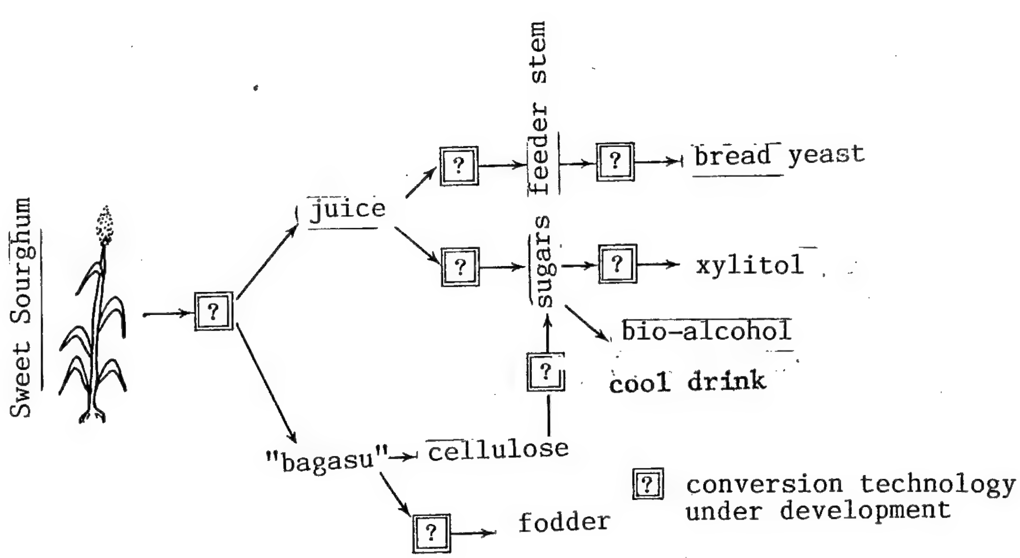

Figure 5. System for Complete Use of Sweet Sorghum

3.4 Oil Crops

Japan produces less than 6 percent of the vegetable oil and fats it needs; even the rapeseed, once a typical oil crop planted on 260,000 hectares from the north to the south, has been reduced to 24 hectares. In America and Brazil, however, attention has recently turned to such things as using oils like rapeseed, sunflower, or soybean in blended oils for diesel engines, the health benefits of vegetable oils containing lots of linoleic acid, and the high value of oil cake as animal fodder. Research is being done on using these crops for biomass resources.

It is not clear when the rapeseed was introduced to Japan, but after the Edo period it was cultivated as a fuel crop in place of sesame or perilla oil.

As noted earlier, little of it is planted now but if it were possible to make it more mechanizable by miniaturization and shortening the stem or raising its yield by hybridization or crossbreeding, farming villages might once again be awash in yellow in the spring--from biomass resources.

The sunflower is increasingly being planted around the world as an oil crop, rivaling the soybean not only in its high yield of oil and fats, but also its content of beneficial unsaturated fatty acids (lineolic acid, linolenic acid). Because it needs a cool, dry climate, however, it is rarely planted in Japan outside of Hokkaido. Experiments to date with a variety called "IS897" in Hokkaido have achieved desirable results: 2-3 tons of seeds per hectare, containing approximately 45 percent oil, more than 70 percent of its lineolic and linolenic acid. In addition, the massive amount of its total output including leaves and stalks--50 tons per hectare in contrast to corn's 6 tons--make it very promising as a biomass crop. In addition to increasing its yield by hybridization, making it resistant to schlerosis and improving its resistance to moisture, future research is needed to achieve a system for its complete use as shown in Figure 6.

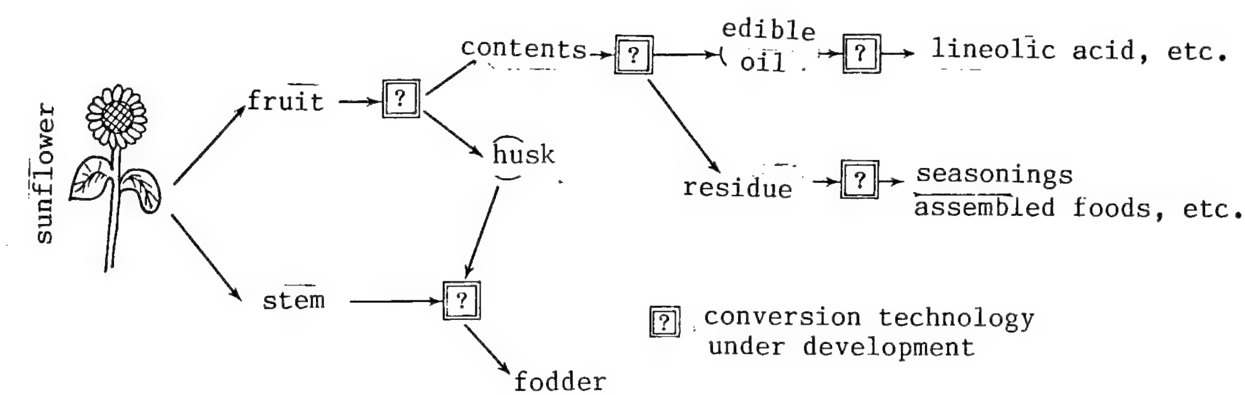

Figure 6. System for Complete Use of Sunflower

3.5 Water Hyacinths

The water hyacinth, mainly a nuisance weed common in the tropics and sub-tropics, inflicts considerable damage on agriculture. It thrives even in Japan in the warm areas west of Toyama and Ibaragi, clogging waterways and putrefying the air.

The water hyacinth is thus treated as a nuisance, but because of its high dried yield of 40-50 tons/hectare (in America) it is expected to be used as a biomass plant in tropical countries.

The current amount of water hyacinths in Japan is said to be 7-25 dried tons/hectare, but its vulnerability to cold makes stable production difficult.

Until now a variety of research has been done in such areas as ways of selecting high yield breeds and propagating by seed, harvesting by crane, dehydrating juice by centrifuge, and concentrating juice by functional macro-molecules, and techniques of generating methane gas, ensilage, and heavy metal adsorption; individually they have already reached the stage of application, but comprehensive systems for using them have not been established yet.

4. Conclusion

Amemiya has offered the following six points to consider in growing biomass plants on farm land:

1) They should not compete with food production
2) Planting must be suited to local conditions
3) Drying must be easy and have a high yield
4) They should dovetail with other crops
5) They should be simple to harvest, store, convert and use
6) Avoid reducing fertility and disturbing the ecology

Creating a local system in combination with fields like animal husbandry while keeping in mind these points is the challenge for biomass research by the Ministry of Agriculture, Forestry and Fisheries.

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CSO: 4306/1167

ELECTRONICS

HITACHI'S FINANCIAL PERFORMANCE DISCUSSED

Tokyo TOSHI KEIZAI in Japanese Dec 85 pp 56-57

[Interview with Yasuo Miyauchi, vice president of Hitachi, Ltd.: "Twenty-five-Percent Decrease in Operating Profits This Fiscal Year, Aiming for 20-Percent Profit Increase Next Fiscal Year"; date and place not specified]

[Text] Hitachi Expects To Register First Sales Drop in 10 Years, First Profit Drop in 11 Years

[Interviewer] With the stock of Hitachi regarded as a barometer for blue chips, Hitachi's business performance draws attention on stock exchanges because of its big influence on blue chips as a whole. In the business results for the first half of fiscal 1985, announced recently, Hitachi registered a sharper-than-expected profit drop--a 24 percent fall in operating profit and a 17 percent decrease in recurring profit--on a sales gain of 3 percent, although the recurring profit decline was somewhat moderated by the improvement in the balance on financial items.

There is great interest in the company's business performance in the second half of fiscal 1985 and in the next fiscal year at a time when the company is facing a number of unfavorable factors in the business climate, such as the semiconductor recession, a slowdown in VTR sales, trade friction, suspension in China-bound exports and the strong yen.

Miyauchi: The semiconductor recession is the biggest cause of the business deterioration. Hitachi's semiconductor sales totaled ¥540 billion in the last fiscal year. For the current business year, the company initially expected its sales to level off from the previous year at the worst. In reality, however, sales amounted to only ¥215 billion in the first half of the year (note: ¥271 billion in the same period of the previous year) and are likely to total around ¥430 billion for the entire year.

In addition to a sales slowdown, declining product prices had more effect on the company's profitability.

[Interviewer] Prices of mainstay 256K DRAM's, which stood above ¥1,000 until around May, are reportedly slipping below ¥400 recently.

Miyauchi: Although such low-priced products are seen on the market in part, circumstances differ among makers. There are companies which boast product reliability and have good customers who purchase products on a stable basis. There are frontrunners and latecomers among makers. Hitachi, being a front-runner, has good customers and does not have to force its way in sales. As a matter of fact, the company is fully producing 256K on a monthly scale of 8 million chips.

[Interviewer] However, the semiconductor recession has yet to show signs of improvement.

Miyauchi: It must be expected that the recession should persist until the middle of next year. However, the worst period seems to have passed as the BB ratio (note: ratio of orders received against shipments) has recently bounced back to around 0.8 from the record low of 0.58 (note in December 1984).

[Interviewer] In announcing the business results for the first half of the current fiscal year, Hitachi projected its sales for the entire year at ¥3 trillion (note: 1-percent decrease from the previous year), recurring profit at ¥193 billion (25 percent less), and net profit at ¥96 billion (9-percent decrease). What about previous records of sales and profit drops?

Miyauchi: These are the first sales declines in 10 years, since FY 1975, and the first profit decline in 11 years, since FY 1974.

Strong Yen, Trade Friction To Decrease Exports 11 Percent

[Interviewer] In addition to the semiconductor recession, influence of the yen appreciation is a growing concern.

Miyauchi: Up to this time, as the yen exchange rate was calculated at 230 to the dollar, it could, of course, generate an exchange loss if the present rate of 210-220 continues.

At present, the company has a dollar income of about $900 million on a semi-annual fiscal basis, including some $750 million in U.S. dollars. But on the other hand, payments for imports amount to about $200 million and a net $550 million would be affected by the appreciating yen. However, the actual influence is believed to be smaller because the loss can be offset through price increases on some products. An estimated exchange loss of about ¥4 billion in the last fiscal year would incur at the yen exchange rate of 210. Nevertheless, the financial loss is not so great because an exchange profit of ¥700 million was registered in the first fiscal period.

The company is more concerned that the appreciating yen would lower the competitiveness vis-a-vis overseas makers in some products. It forecasts that its exports for the current fiscal year would fall 11 percent from the previous year to about ¥996 billion. In contrast, it expects that domestic sales would increase around 5 percent to ¥2,004,000,000, a relatively good performance.

[Interviewer] The Hitachi group earlier announced a huge project to expand imports from the United States as part of the policy to alleviate trade friction. According to that, it is attaining imports from the United States to about $400 million annually by the end of 1986--through emergency imports of $120 million in addition to the approximately $260 million. In that sense the strong yen had made it easier to attain the goal, but on the other hand, it is believed that in order to avoid trade friction it is necessary to further promote local production in overseas areas.

Miyauchi: Our company already has many local manufacturing companies in the respective countries worldwide. The Hitachi Automotive Products (United States) was established this year for local production of automotive parts.

For strengthening local production of semiconductors, color television sets and VTR's, the company is now expanding the Hitachi Semiconductor (America), Hitachi Consumer Products (Europe) in West Germany, and Hitachi Consumer Products (United Kingdom) in Great Britain, respectively. Local production of computers as a matter of course is also an issue for the future.

Hitachi Spends ¥250 Billion, 8 Percent of Sales, on R&D

[Interviewer] In the business results for the first half of the current fiscal year, Hitachi registered a profit in the balance on financial items ¥10.5 billion more than the previous year (note: from ¥14.8 billion to ¥25.3 billion). Does this mean that the slacking of main business was covered by financial manipulation?

Miyauchi: This resulted in curbing plant and equipment investment. Then there were increases in surplus funds. Thus, it was natural that financial profits increased. However, this is only a subsidiary factor because Hitachi has the basic policy of not placing financial investment strategy in its mainline business.

[Interviewer] What about the special money trust which is popular lately?

Miyauchi: Some ¥100 billion has been invested. It yields somewhat more in interest than the CD's [convertible debentures] and on the repurchase agreement bonds.

[Interviewer] How much is the reduction for plant and equipment investment?

Miyauchi: It was ¥203.5 billion in fiscal 1984 but an initial plan was some ¥200 billion for fiscal 1985. Under the present circumstances, however, Hitachi intends to curb fiscal 1985 investment to about ¥170 billion, by reducing investment in semiconductors to ¥60 billion from ¥90 billion.

However, the expenditures for R&D will be increased. The company spent ¥221.1 billion in fiscal 1984 and expects to expend ¥250 billion in fiscal 1985, which is about 8 percent of its sales.

[Interviewer] This is the highest ever in ratio of R&D to sales. What are the main contents of R&D expenditures?

Miyauchi: As we started a basic research institute this April, most spending is for fundamentals. Hitachi hopes to tackle basic technologies for application toward the 21st century, such as new materials, new energy sources, biotechnology, etc.

Being at Lowest This Fiscal Term, Hitachi Aims at 20 Percent Operating Profit Gain for Next Fiscal Period

[Interviewer] What are the prospects for the next fiscal year?

Miyauchi: The current fiscal year being the lowest, an upturn is foreseen next fiscal year.

[Interviewer] What are the reasons?

Miyauchi: The semiconductor recession may continue until the middle of next year. However, the share of memory chips, particularly the worst among the semiconductors, has fallen in the semiconductor division currently to around 30 percent as compared to more than 40 percent at its peak. Sales of other products, such as microcomputers, logic IC's, etc., continue to be smooth as always.

Hitachi expects its computer sales in the current fiscal year to expand 12 percent over the previous year (note: ¥532 billion) of ¥600 billion, with a company forecast for continual sales increase in the next fiscal year as the lineup of new type machines are progressing.

On top of that, the company can expect increased orders for products relating to power generation plant and equipment investment, and also foresees continued recovery for factory items depending on industrial trends for capital spending. Sales of automobile components are expanding satisfactorily.

In the home electrical appliances department, prices of VTR's have seemed to hit bottom, while sales of video camera-recorders are picking up. The company has lagged in CD sales, but intends to launch a sales drive in the future.

Under these circumstances, the company is aiming at increasing sales in the next fiscal year by 10 percent from the current year and operating profit by around 20 percent although uncertain factors remain such as the yen exchange rate. The company expects its operating profit to regain the level of last fiscal year in the year after next fiscal period [1987].

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ENERGY

NEW ENERGY INTRODUCTION RESEARCH COMMITTEE ON ALTERNATIVE SOURCES

Tokyo SHIGEN TO ENERUGI in Japanese Aug 85 pp 35-64

[Report by New Energy Introduction Research Committee]

[Text] I. Introduction

1. Since its establishment within the Agency of Natural Resources and Energy, Ministry of International Trade and Industry (MITI), in October 1984, the New Energy Introduction Research Committee [NEIRC] has conducted deliberations on six occasions over the November 1984-June 1985 period.

2. With a 10-year history behind it--which included the inauguration of the Sunshine Project in FY 1974, followed by the start of the New Energy Organization (NEDO) in October 1980--efforts for technical development of new sources of energy are bearing fruit at an accelerated rate.

With the enactment of a bill for the promotion of development and introduction of oil-alternative forms of energy in FY 1980, the targets for oil-alternative energy supplies were approved in a cabinet meeting and directed by the MITI minister, thus providing direction for development and introduction of non-oil alternative energy sources.

3. Development of new energy sources is in various technical stages. Some, having completed pilot plant level research, are entering the stage of evaluation and accumulation of technical achievements (such as solar heat power generation, hydrogen manufacturing based on electrolysis of water, etc.). Others are in pilot plant research or are planning to start such research coal liquefaction, coal gasification, etc.).

With research into new sources of energy at various stages of technical development, NEIRC deliberations focused their attention on those forms of energy which, based on the accumulation of technical breakthroughs so far obtained, are considered to have bright prospects for practical applications in view of their cost efficiency.

As for the new sources of energy being deliberated in NEIRC, the course of development is expected to go through the following steps: demonstration operations of new energy resources for practicality, and initial stage

introduction. Depending on the features of these energy sources, a surge in enthusiasm for their introduction can be expected, largely from the private sector.

4. With this in mind, NEIRC has studied and evaluated forms of new energy, including solar light power generation, wind power for electric power generation, solar systems and methanol as fuel, all of which are considered to be candidates for introduction at an early stage. The study and evaluation covered basic elements that need to be solved before their introduction. The subcommittees of the Advisory Committee for Energy and the Electricity Utility Industry Council had proposed in 1982 and 1983 that study begin on the aforementioned energy sources, except methanol fuel, for their future introduction, either as a distributed type of electric power source or as a local energy source, by taking advantage of the advances in research and development so far achieved. As a consequence, current NEIRC research may be called a follow-up study.

NEIRC has added research into methanol as a fuel source in view of advances in research into alcohol's utilization as fuel and also from lower prices in recent years. A subcommittee was simultaneously established to promote research into methanol's use as a fuel for internal combustion engines, in particular.

II. General

1. Basic Points Involved in New Energy Introduction

(1) New energy sources have until now been considered as a quantitative alternative to oil, lowering the country's reliance on oil for its energy requirements. But recent easing of constraints on oil supply has made it possible to take a fresh look at the energy problem with a view to establish a best mix of energy sources according to demand. That new sources of energy can be regarded not only as alternatives to oil, but also can be evaluated from the viewpoint of energy characteristics, costs, and national economic security, is a new idea. How oil prices will move has a great impact on the economics of new energy sources. However, making efforts to realize a best mix of energy supplies, including new energy resources, is an important task for Japan if it is going to secure energy supplies on a long-term, stable basis. What is required, of men both in and out of office, is that they not be distracted by the prevailing short-term situation surrounding oil, but make efforts to foster new energy sources as future energy resources so that they can be brought on the market at the earliest possible date.

(2) New energy sources involve much work on element technologies, including systems technology. Breakthroughs in new energy technology are expected not only to have ripple effects on similar technologies in other fields, but also to contribute to improvement of the manufacturing process in existing industries. Furthermore, by participating in the projects for new energy technology development, the conventional energy industry may succeed in transforming itself into a comprehensive energy industry.

(3) If transferred to other countries in a way befitting energy utilization in those countries, the vast amount of pioneering new energy technology Japan has accumulated will contribute to stability in world energy supply and demand to the world economy. New energy technology is, therefore, a field with vast potential for international cooperation.

2. Points To Consider in Introducing New Energy Sources

(1) What role a new energy source should be given in the overall picture of energy supply must be determined not only by whether it is an oil alternative energy source but also by whether demand exists for energy with its features. Simultaneously, consideration will have to be made on such factors as the new energy source's relations with existing energy sources and its stability as an energy source. The following five points have been established as criteria for evaluating energy sources.

① Availability of sufficient supply (volume aspects)

--The ratio of available supply to estimated demand

--Secure supply

② Efficiency and ease of handling or use as energy (quality aspects)

--High energy efficiency, ease of handling or use, high quality and stability, in comparison to existing energy sources

--Compatibility with the environment

③ Price competitiveness with existing energy sources (cost aspects)

--Price stability

--Economics based on long- and medium-term perspectives after taking into account such factors as additional costs for maintaining distribution channels, quality in the wake of changes in energy utilization systems, and reliability and durability of machinery and equipment needed for the new energy source

④ Response to the vulnerability in primary energy supply (aspects of national economic security)

--Existence of a balance in supply of primary energy resources

--The degree of dependence on a specified country and/or area when crude fuel has to be imported

5 Maintaining a smooth transition when introducing new energy sources (aspects of smooth introduction)

--Relations with existing energy systems (smooth coordination, attention to user benefits or convenience)

--Impact on existing industries (including nonenergy industries)

Besides paying attention to these five points, consideration also must be made of the following items:

① Compatibility between utilization of market mechanisms and government policies such as low-cost financing at initial project stages

② Various industry-promotion systems, including tax systems

③ Harmony between an energy project and the international energy supply and demand situation and trade in energy resources

(2) When evaluating each of the new energy sources under consideration by NEIRC against these general yardsticks, each has problems. The following are the most pressing.

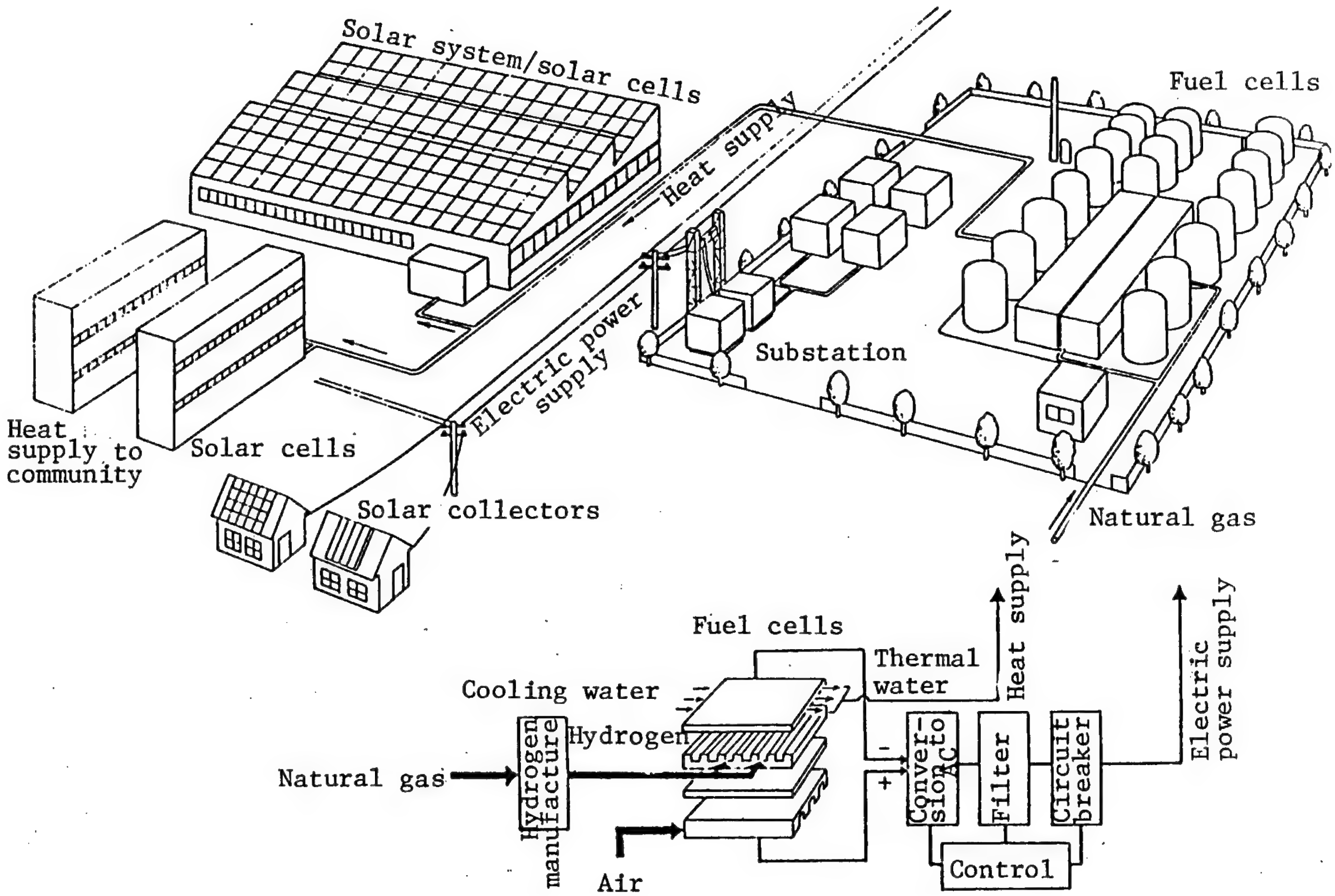
Power Generation Based on Sunlight

① When estimates are made on the basis of results of technology development achieved so far, the costs of power generation based on sunlight (system price: ¥800-1,200/Wp) are expected to drop, after studies have been made for the practicability of solar cell manufacturing technology, to the level of diesel-fired power generation by 1990. But markets are limited, so if solar light power generation is to achieve a cost (system price: ¥240-270/Wp) believed to generate large demand for the system, R&D of new element technologies is inevitable. (Price constraints)

② When electricity is to be fed into a certain scale power grid from scattered sunlight power generating systems, studies will be needed on the practicality of the interconnected system for coping with fluctuations in voltage, higher harmonic, etc. Furthermore, if interconnected systems have a widespread diffusion, what effect weather changes will have on the efficiency of the total power supply system is an issue requiring analysis and evaluation. (Quality and smoothness)

Fuel Cell (Phosphoric Acid Type)

① Small-to-medium capacity fuel cells of the on-site or dispersed installation type are expected to be put to practical use around 1990. System manufacturers need to respond to user demand by establishing the technology to manufacture small-sized reforms and high-performance cells at low costs. (Price constraints)



Energy Supply System Using New Energy Source (example)

② When electricity is to be fed into a certain scale power grid from scattered on-site type fuel cells, studies will be needed on the practicability of the interconnected system for coping with fluctuations in voltage, higher harmonic, etc. Furthermore, if interconnected systems have a widespread diffusion, what effect operating methods of fuel cells (operations as a result of a demand for heat) will have on the efficiency of the total power supply system is an issue requiring analysis and evaluation. (Quality and smoothness constraints)

Power Generation Based on Wind Power

The task here is for small-to-medium scale systems to bring their costs down through mass production. Surveys covering the entire nation are needed to see if there actually exists any demand for electricity based on wind power, beginning with a survey on the amount of resources. (Price constraints)

Solar System

Solar systems for household use are coming to be widely used. However, if they are to find a much larger market, the time from an investment on a system to the recovery of the invested money needs to be shortened. Hence, with a goal of recovery of invested money within 5 years, a level considered technically feasible, tax incentives as well as improvement in manufacturing technology of solar systems are needed. Solar systems for industrial use are at a stage where the technology for practical use is being developed. But here a much shorter period is being demanded for the recovery of an investment on systems, requiring efficient promotion of technical development. (Price constraints)

Fuel Methanol

① In the case of methanol as a fuel for automobiles, technical development is focusing on the automobiles themselves. Whether methanol is to be used as a fuel for automobiles or for power generation, research is needed to prove its compatibility with the environment. (Quality constraints)

② A study is needed to see if large supplies of methanol can be had at low cost and on a secure basis. (Volume, price and economic security of the nation constraints)

③ An infrastructure needs to be built toward a smooth introduction of methanol, while paying attention to what impact its introduction will have on the consumer and related industries. (Disruption constraints)

3. Steps for Introduction

(1) Long-term perspective

Each of the new energy sources targeted for the NEIRC study has technical advantages as energy producers, and they will be introduced where their merits can be best utilized. What role will new energy sources have in the country's overall energy supply after the constraints detailed above have been overcome? The following are long-term perspectives.

Power Generation Based on Sunlight

If solar systems are going to achieve power generating costs competitive with those of electricity supplied by utilities to general households, the following technical breakthroughs are needed. Development of element technologies, such as the technology to refine SOG silicon from low-quality silica and silica sand, solar cell technology incorporating multicrystal thin-film silicon, multilayered battery technology, and high-performance amorphous solar cell manufacturing technology are all needed. Also needed are adoption of an integrated system-roof module that has no need for a rack, and establishment of an interconnected system that does not use any storage batteries (generation of electricity in homes).

In this case, supposing solar systems are to be installed on the roofs of single-family houses and apartment buildings, the total output of electricity nationwide could reach some 20 million kwp under certain sunshine conditions.

Fuel Cell (Phosphoric Acid Type)

Utilization of on-site type fuel cells is expected to advance in large cities where city gas supplies are based on natural gas, or in industrial parks where hydrogen gas is readily available as a byproduct (on-site type combined heat and electric power supply). If estimated on the basis of heat requirements in relatively large industries and buildings, the total output of electricity generated by fuel cells is expected to reach around 10 million kw.

Power Generation Based on Wind Power

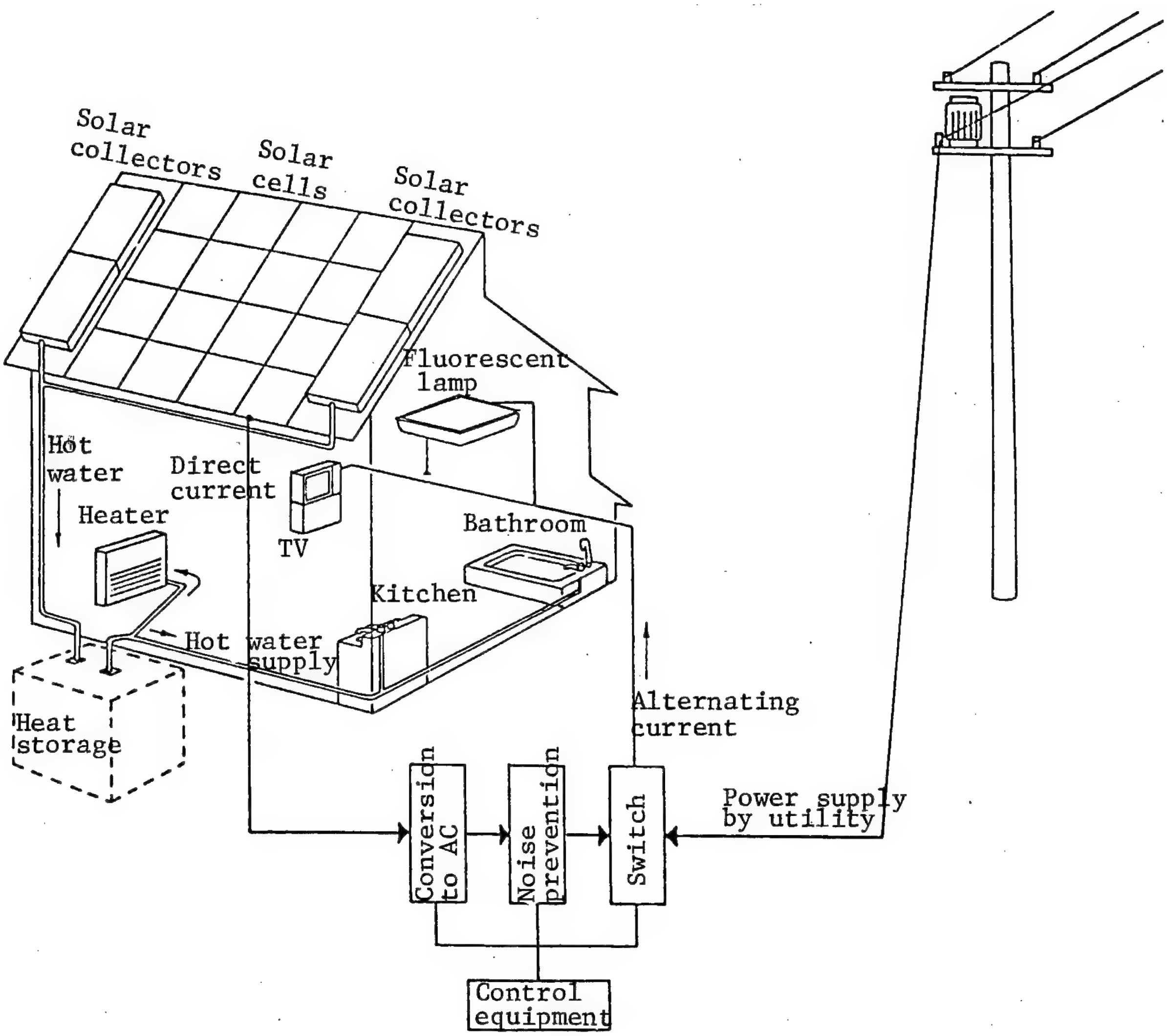
The cost of wind power generation is expected to drop to a level where wind energy can be tapped cost-effectively for power generation, in combination with a diesel generator in remote islands (a combination of wind power and diesel for power generation). In this case, the maximum output of the wind power system is limited to the capacity of the existing diesel generator (about 400,000 kw). The latent demand for wind turbines (in the order of several kilowatts in output) is expected to reach around a million units for use in such places as agriculture, stock breeding and fishery industries, sightseeing and leisure facilities and radio stations.

Solar Systems

The latent demand for household solar systems is expected to reach approximately 20 million units, while business and industry circles are considered to have a demand for about 1 million units each. With the realization of a shortened period for recovery of capital investment into a system, the demand for solar systems is expected to far exceed their current diffusion level of about 1 in 100 family houses.

Methanol for Use as Fuel

Were methanol to be competitive with oil in price, to be compatible with the environment, even when consumed in large quantities, and were it to be supplied on a secure basis, alcohol would have the potential to become a leading alternative fuel to oil in thermal power plants. If methanol is to be used as a fuel in thermal power plants, about 1 million tons of the alcohol will be needed to generate 300,000 kw of electricity annually. As for methanol's application in automobiles, alcohol could prove to be a new fuel after gasoline and diesel oil, provided that technology is developed for automobiles that burn high-density methanol, and that a distribution system is established for high-density methanol.



System for Private Housing Using New Energy Sources (example)

(2) 5-year prospects for introduction of new energy sources

New energy sources will probably begin to be introduced, including demonstration introductions, gradually over the coming 5-year period along the lines of the long-term prospects mentioned above. This 5-year period is a sort of "approach run" for the new forms of energy. The "take-off" period marking their practical application is expected to be in or around 1990, provided that the various requirements pointed out in this paper have been overcome, and that necessary measures have been implemented according to the specific manner of introduction for each of the new forms of energy.

The following table shows how and where each of the new energy sources will be introduced over the coming 5 years.

Energy	Form of introduction in approximately 1990	Field of introduction in approximately 1990
Sunlight power generation	Use as small-size independent power sources	Use in a combination with diesel generators in remote areas
Fuel cell (phosphoric acid type)	Experimental use as on-site systems	Practical use in on-site systems
Wind power generation	Use as small-scale systems	Use in combination with diesel generators in remote areas
Solar system	Use as household systems	Expanded use of household systems, practical use of systems for industry

(Note) Demonstration tests of methanol as fuel are expected to continue until around 1990 to study its compatibility with the environment when used as a fuel in power plants, and to determine its practicality as a fuel for automobiles. Alcohol's introduction is expected after that period.

(3) 10-year prospects for introduction of new energy sources

At a cabinet meeting held in November 1983, it was decided that the target for FY 1995 is to have supplies of oil alternative energy sources (energy sources mostly composed of the new energy sources being discussed in this paper, except for fuel cells) equivalent to 1.5 million kiloliters in oil.

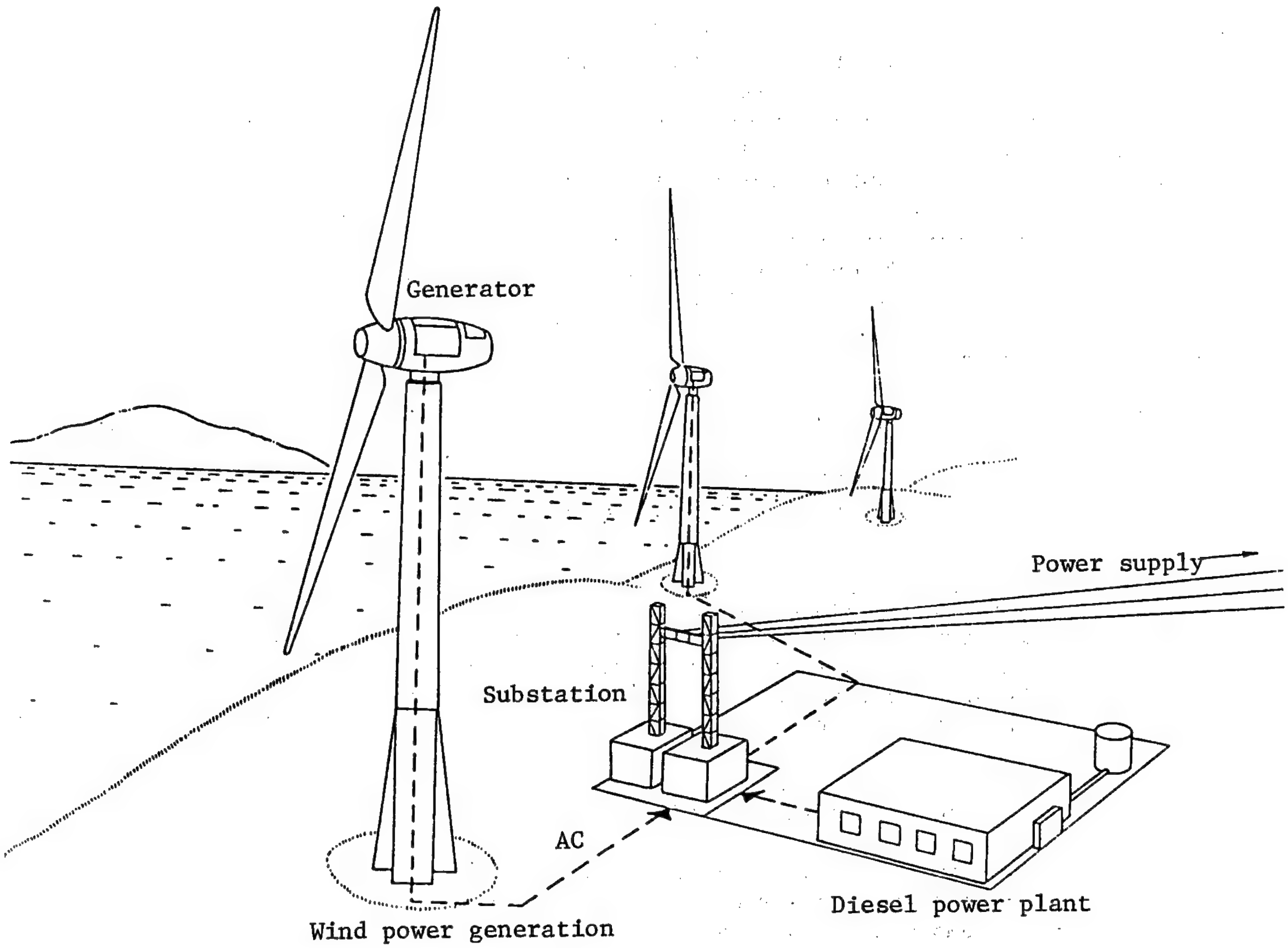
As described above, up until around 1990 the markets for the new energy sources in question will expand at a leisurely pace. The next 5 years may be considered a sort of approach run, and the takeoff for their introduction for practical application is expected to arrive about 1990. After 1990, new energy introduction, it is anticipated, will follow a sharp upward curve, provided necessary measures are implemented in keeping with the prevailing situation, successfully achieving the goal of the equivalent of 1.5 million kiloliters in oil.

4. Current Priority Tasks

(1) Common tasks

① Policy measures in the initial phase of new introduction

From now, private industries will be increasingly playing a leading role in the introduction of the new energy sources under study by NEIRC. In



Wind Power-Generating System on Remote Island

the initial phase of their introduction, however, it is often the case that technical development of such energy sources entails risks and new energy sources are often not competitive with the existing energy sources in cost efficiency. The initial phase of introduction, on the other hand, is for mastery of the manufacturing techniques and systems achieved in the process of meeting user demand, and for enlightening latent customers to the benefits of the new energy sources. The government, for its part, is requested to come up with necessary measures for accelerated introduction of new energy sources, after considering their long-term features for the country's energy supply. Such promotional measures include granting of subsidies to cover risks in technical development, other forms of financing, and tax incentives. But an equilibrium needs to be maintained between those measures and other aid systems, by paying attention to the market mechanism which is based on the competitive power of new vis-a-vis existing energy sources. Worthy of study as another form of government policy to encourage

introduction of new energy sources in their initial introduction phase is drafting of a time schedule for their introduction into public facilities.

② How to promote international cooperation

For varying reasons, such as the endowment of natural resources and prevailing economic conditions, not a small number of countries in the world are in need of new energy resources. Transferring new energy technologies developed in Japan to those countries as demanded will not only contribute to their economic development through lessened pressure of energy problems and an improved international balance of payments, but will also help to ease world energy problems and bring stability in the world economy.

International cooperation, on the other hand, is expected to have an effect of further accelerating and raising the efficiency of R&D activity in Japan, and of promoting the introduction of new energy sources, thus contributing to the twin cases of technical progress and practical application.

International cooperation could take various forms: cooperation with the advanced countries; expansion of cooperation to developing countries; cooperation in projects in third party countries not including Japan; bilateral cooperation. It could also take the form of technical transfer and joint research, but the basic attitude should be to expand cooperative projects as much as possible.

③ How to promote standardization

Standardization is an effective means of raising the level of technology. Therefore, as for those new energy technologies that have reached a certain technological stage of development, efforts should be made toward establishing standards or specifications on the basic equipment, machinery and systems in a way that would create competition in the markets for such equipment and systems, thus contributing to lowering their costs. The standards and specifications should be universal, applicable not only in Japan but also in other countries. In this respect, Japan will have to assume leadership in the effort towards worldwide standards and specifications.

④ Tasks common to dispersed types of power sources (in this paper, these include power generation based on sunlight, fuel cells, and wind power)

--Depending on the form and/or scale of their introduction, dispersed types of power sources may give suppliers of ordinary electric power added burdens in the forms of protecting or safeguarding power grids and power loads by disrupting existing power supply systems. Adjustments, therefore, need to be made between dispersed types of power sources and existing power supply systems before the former are introduced.

--The effects of new dispersed types of power sources, in particular, on existing power supply systems are greatly different from those of conventional power sources like gas turbines. In their introduction, thorough

studies need to be made on such points as the features of the energy source, what priority the energy source should be given in the nation's energy supply system, and what burden the energy's introduction would bring on the ordinary consumer of electricity.

--For raising the quality of its power supply and for realizing effective utilization of its equipment, a dispersed type of power plant, like a power generating sytem using sunlight, in fact, often must seek the help of the regional electric power company in obtaining a parallel supply of electricity to the latter's power supply system or in securing reserve electricity. Studies are needed on how these arrangements should be put into place. Studies are needed, in particular, on such technical tasks as suppression of harmonics, maintenance of quality of electric current including voltage fluctuations, measures for preventing trouble in new energy sources from spreading to regional power supply systems, measures to cope with inverse currents, etc. Verification studies are also needed on the operability of the regional power supply system if it is to be connected to a large number of power sources of the dispersed type.

--Moreover, these dispersed-type power sources differ greatly from existing power-generating systems in respect to equipment safety, maintenance and operation, so related technical standards need to be established. Studies are also needed on their maintenance.

--The problems described above are also regulatory problems, so an administrative factor is required to implement necessary measures in keeping with advances in practical use of electric power sources of the dispersed type.

(2) Individual tasks

Power Generation Based on Sunlight

--R&D activity needs to be intensified for the system's full-fledged utilization (achievement of costs competitive with those of power supplies to general households). To that end, breakthroughs in technology are being called for. In selecting technical tasks requiring solutions, full-fledged evaluation is needed to clarify and define what they are, and the possibility of international cooperation in their research and development needs to be explored to realize efficient and speedier execution of R&D work.

--If R&D on the polycrystal solar cell manufacturing technology, a project now underway, is to be improved to a level involving the technology's practical demonstration, breakthroughs will lead to initial-phase demand for systems incorporating the technology. Studies are required to determine under what R&D structure the research should be promoted, including the share of funds required to execute the project that needs to be borne by the private sector.

Fuel Cells (Phosphoric Acid Type)

--As for the on-site type of fuel cells, the following two types of systems must be considered. One is a system for business uses based on city gas, and the other is a system for industrial uses utilizing byproduct hydrogen produced in chemical or steel plants. These two are expected to reach the stage of introduction on an experimental basis. Because R&D for those systems still contains risks and because those systems that will be introduced for practical application are not uniform in structure, each with its specific features depending on where it is to be installed, studies are needed on the way in which research for them should be advanced, including the share of research money to be borne by the private sector, and the issue of user participation in the research.

--As for large-scale systems for electric power companies, we must examine the way in which R&D is to be promoted by taking into account the results of test-running of the 1,000-kw class plant currently underway, and the molten carbonate type of next-generation technology.

Power Generation Based on Wind Power

If wind power is to find a place as a power source for small-scale power generation, or in combination with diesel generators, for electricity in remote islands, the prerequisite is to obtain detailed data of individual sites targeted for system installation. Surveys are needed across the nation to determine the feasibility of introducing wind power systems (including surveys of wind conditions, evaluation of the system's economics, and conceptual design of the system to be introduced). How such surveys should be advanced needs further study, including study of the structure for promoting such surveys.

Solar Systems

It is demanded that costs of solar systems come down steadily in the future. To that end, the technical capabilities of both the private and government sectors must be mobilized effectively. They must enact necessary policy measures for promoting technical progress in the private sector, in order to bring the costs of solar systems, particularly those for industrial use, drastically down.

Methanol for Fuel

The first requirement for methanol is development of the technology to utilize alcohol as fuel, including demonstration of the fuel's compatibility with the environment. The next step is a thorough study of how the energy source can be introduced at competitive costs on a secure basis.

III. Particulars

1. Power Generation Based on Sunlight

(1) Features

Features of power generation based on sunlight are the following:

① Power-generating systems utilizing sunlight have no need for fuel since they utilize sunlight as their energy source. They do not place any load on the environment since they do not burn any fuel.

② Since they have no moving parts, they do not generate any noise and are easy to maintain.

③ Since solar cell systems are of a modular structure, they are suited for mass production and are highly flexible in scaling up or down.

④ Solar cells generate electricity in the form of direct current, so a converter is necessary when using the output as alternating current.

⑤ Since they use sunlight as their energy source, they are subject to fluctuations in their output due to weather.

(2) Status

① Research and development

The following advances have been achieved in R&D of power-generating systems utilizing sunlight.

--R&D has continued, since FY 1974, under the Sunshine Project, on manufacturing and utilization systems.

--R&D has continued on utilization technology under the New Materials and Machinery System Development for Apartment Houses, a project started in FY 1984.

--The private sector has also been actively engaged in technical R&D.

② Status of introduction of products and prices

--Status of introduction of products

- --Solar cells are currently widely used as alternatives to button batteries, mainly in consumer products such as calculators.
- --As a source of electricity, there are some cases in which solar cells have been put to practical use in specialized cases such as in remote and unmanned facilities.

--Of the FY 1983 production of solar cells equivalent to 4.8 Mw of electricity in Japan, about 3.5 Mw capacity was accounted for by consumer amorphous cells (for use in calculators and watches).

--Costs

--The costs of solar cell modules have dropped sharply from the ¥20,000-30,000 level per wp in 1972 to ¥1,500 per wp in 1984.

--The costs of peripheral equipment such as inverters were in the ¥1,100-2,200 range per wp in 1984.

(3) Economic feasibility, fields targeted for introduction and number of products introduced

① Prospects for bringing costs down

--It is very difficult to bring the costs of single crystal solar cells below ¥1,000 per wp (1985 price. The same shall apply hereafter) since large amounts of energy are needed to manufacture high-purity silicon, the raw material.

--As for polycrystal solar cells, the Sunshine Project aims to lower their costs to ¥500 per wp by 1990.

--The costs of peripheral equipment (excluding batteries), except for modules, are expected to come down to the ¥300-800 range by 1990.

--From the foregoing, the cost of a whole system comprising solar cell modules and peripheral equipment, that now ranges from ¥3,000 to ¥4,000 per wp, is expected to drop to ¥800 to ¥1,200 per wp by 1990.

--The long-term goal of power generation using sunlight, that is, to bring the costs of solar power generation to the levels of utility charges for electric power supplies, means that the costs of power generating systems must be reduced to the levels of ¥240 to ¥270 per wp. To that end, R&D is needed, but before embarking on R&D, many more technical breakthroughs are required in polycrystal and amorphous solar cells.

--In considering the current costs of solar cells, attention needs to be paid to the fact that an expansion in the embryonic market for solar cells, now centered on the demand for their use as independent power sources, may help bring their costs down.

② Fields considered fit for introduction of solar cells and the latent amounts of power generation available with solar cell systems

After taking into account the fields considered candidates for introduction of power-generating systems based on solar cells, and the corresponding sunshine conditions and system installation areas, the latent amounts of power generation based on solar cells are as follows:

--For use as independent power sources

In this field, the demand for solar cells is gradually emerging for their use as power sources for radio relay stations and streetlamps. It is difficult to come up with an exact figure because a wide gap exists between the user-demanded cost (a cost competitive with those of existing energy sources) and the supply cost of solar cells, but it is expected that there is a latent demand for 400,000 to 800,000 kwp levels of electricity.

--For use as power sources on remote islands

Solar cells are expected to replace part of electricity generated by diesel generators on remote islands (400,000 kw). In this case, the user demanded cost is from ¥50 to ¥90 per kwh (¥440 to ¥800 per wp), and latent demand is expected to be in the 20,000 to 40,000 kwp range.

--For use as power sources in public facilities and offices

When solar cells are to be used as power sources in public facilities and offices, the user demanded cost is ¥28 to ¥34 per kwh (¥250-300 wp), about the same as the costs of electricity for business use. Latent demand could reach 3.6 million to 5.2 million kwp (the total of solar cells installed on roofs).

--For use as power sources in homes

When solar cells are to be used as power sources in homes, the user demanded cost is ¥27 to ¥31 per kwh (¥240-270/wp), about the same as the costs of electricity for lamps in homes. Latent demand could reach 17 million to 27 million kwp (the total of solar cells installed on roofs).

--For use as power sources in industry

When solar cells are to be used as power sources in industry, the user demanded cost is ¥15 to ¥29 per kwh (¥130-250/wp), about the same as the costs of large-lot and small-lot power supplies to industries. If those price levels are achieved, latent demand could reach 10 million to 14 million kwp (the total of solar cells installed on roofs, etc.).

Given the user-demanded costs in cases other than those where solar cells are employed as independent power sources, and the aforementioned prospects for reductions in the costs of solar cells, even if the cost of manufacturing solar cell modules dropped to the ¥500/wp level (system cost: about ¥800-1,200/wp) by about 1990, fields where introduction of solar cell systems would be feasible would still be limited. However, even at these costs, the demand for solar cells is expected to be fairly large for their use as independent power sources. Moreover, as solar systems come to be widely used, consumer familiarity with power generation based on sunlight is expected to increase. The government should come up with some measures for accelerated introduction of such systems into public facilities.

(4) Priority items for practicalization of power generation based on sunlight

① Tasks for medium-term R&D and for accelerated introduction

The tasks for medium-term R&D and for accelerated introduction until about 1990 are the following:

--Low-cost modules

R&D on techniques for high-performance polycrystalline solar cells and their mass production is needed towards the goal of achieving the ¥500/wp cost level by about 1990.

--Low-cost peripheral equipment

Besides elevating their performance, the costs of peripheral equipment and devices making up solar systems need to be lowered through standardization and demonstration operations.

--Tasks involving a solar system's capacity to meet demand

Solar systems cannot generate electricity during the night,and their output is also subject to fluctuations depending on the season, weather, and natural conditions. When solar systems are to be used in places where access to large-scale electric power systems is difficult, a hybrid system needs to be developed whereby a solar system is used in combination with a diesel generator.

--Tasks concerning accelerated diffusion

If power-generating systems based on sunlight are to find wide application, their costs need to be brought down through increased demand and their utility also must be recognized through their demonstrated operations. Necessary measures must be taken for their promotion that are well balanced with the positive utilization of market mechanisms. In this case, how to introduce solar systems into public facilities is a matter for serious study.

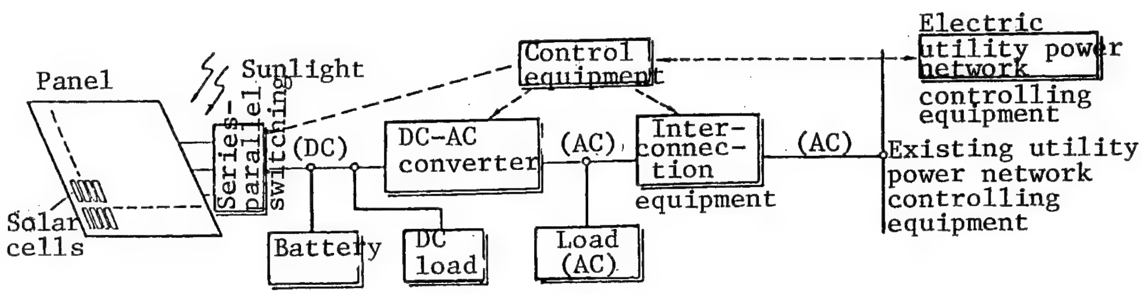
② Long-term R&D tasks

If power-generating systems based on sunlight are to find applications in broad fields, their costs (system price: ¥240-270/wp) will have to be lowered to levels compatible with those of electricity supplied to ordinary homes (¥27-31/kwh). To what end, R&D on basic technologies, such as manufacturing technology of low-cost silicon, manufacturing technology of high-efficiency polycrystalline thin-film silicon cells, and manufacturing technology of high-performance and high-reliability amorphous silicon cells, is needed.

--Types of solar cells

- Solar cells
  - Silicon
    - Crystalline cells
      - Single-crystal cells
      - Polycrystalline cells
        - Ribbon method
        - Cast method
    - Amorphous cells
  - Others
    - SnO_2
    - II-IV group (CdS, CdTe, etc.)
    - III-V group (GaAs, etc.)
    - Others

--System composition of power generation based on photovoltaics



--Features of power generation based on sunlight

Advantages

1. Solar plants are nonpolluting.
2. Since they have no moving parts, and are not subject to high temperature or pressure, they need little maintenance and can be operated unmanned.
3. Solar energy is a renewable energy source.
4. Since photovoltaic plants are modular, they can be produced in large quantities.
5. Solar plants can be designed freely as needed, from small-scale plants to large-scale plants.

Disadvantages

1. The output of solar power is affected by available sunlight.
2. Because of the low energy density of sunlight, a large tract of land is required to obtain a large output of electricity.
3. The costs of solar photovoltaic cells at present are high.
4. Solar cells generate direct current. (This feature is a plus in some cases.)

2. Fuel Cells (Phosphoric Acid Type)

(1) Features

Fuel cells have the following features:

① Electric output is directly obtained by an electrochemical reaction of fuel (hydrogen) and oxygen. (Direct current output)

② Power-generating efficiencies are in the 40-45 percent range. When waste heat is utilized, total thermal efficiency climbs to more than 80 percent.

③ Highly responsive to loads, they have far fewer problems with respect to air pollution and noise.

④ Since fuel cells are modular, they can be easily installed, and their installed scale can be changed with a high degree of flexibility.

(2) Status

① R&D of fuel cells is as follows:

--Under the Moonlight Project started in FY 1981, R&D has continued on fundamental technologies of fuel cells and a 1,000-kw class power plant.

--R&D has continued on utilization technology under the New Materials and Machinery System Development for Apartment Houses, a project started in FY 1984.

--Private industries, including electric power companies, city gas companies, and equipment manufacturers, have been taking part in development projects in the United States and/or have been engaged in their own research.

② Status of systems introduced and costs

--Systems introduced

No commercial fuel cell system has yet been introduced at home or abroad, but Japan has introduced several systems from the United States for test operations.

--Costs

Costs of fuel cells diverge widely since they are still in experimental stages. A large-scale test system (4,500 kw) introduced from the United States, the leader in the field, for example, costs about ¥1.1 million to generate a kilowatt of electricity (installed cost). Similarly, a small test system (40 kw) costs about ¥3.75 million per kw. The installed cost of the 1,000-kw plant Japan has built under the Moonlight Project is about ¥3.2 million per kw.

(3) Economics of fuel cells in the future, probable fields for introduction of fuel cells, and quantity of fuel cells introduced

① Prospects for reductions in costs

The U.S. GRI Project (a project for commercialization of fuel cells promoted by the Gas Research Institute of America, with participation of Japanese city gas companies. It has been underway since 1977 with financial assistance from DOE) expects that the costs of 200-kw plants will be ¥500,000 to ¥750,000 per kw in their initial introductory phase (for several years from 1987) and that thereafter their costs will drop to levels of ¥200,000 to ¥250,000 per kw in the period when the market for such plants has matured. As for developing on-site type fuel cell plants in Japan, their costs are expected to drop to levels of Y1 million per kw within a few years, depending on R&D advances, and further cost reductions are expected as the number of such plants installed increases.

② Fields where introduction of fuel cells are considered feasible, and latent amounts of fuel cells that may be introduced

Candidate fields for introduction of fuel cells and corresponding quantities of fuel cells that those fields may introduce are as follows:

--For use in businesses

User-demanded costs of fuel cells for use as power sources in hotels, restaurants, hospitals, etc., is in the ¥330,000 to ¥490,000 per kw range, when taking into account electricity rates for business use charged by the electric utilities, and given the advantage that fuel cells also provide heat. Based on the demand for heat, there may exist latent demand for the equivalent of 3.5 million to 7 million kw of electric power in fuel cell output.

--For use in plants

The user demanded cost of fuel cells for use as power sources in factories is in the ¥320,000 to ¥490,000 per kw range when taking into account the fares of small-lot electric power supplies charged by the electric utilities, and the heat advantages of fuel cells. Based on the demand for heat, there could exist latent demand for the equivalent of 500,000 to 1 million kw of electric power in fuel cell output.

--Fuel cells for installation in empty lots in substations

The user-demanded cost of fuel cells to be installed in unused spaces in substations and so forth is calculated to be in the ¥320,000 to ¥470,000 per kw range based on the costs of electricity for business use. Assuming fuel cells are to be installed in substations under conditions such as voltage level, latent demand is expected to reach 2 million to 4 million kw.

--Fuel cells as replacements for thermal power plants

The user-demanded cost of fuel cells as power sources that take the place of small- to medium-scale thermal power plants is about ¥190,000 per kw, about the power-generating cost of LNG-fired power plants. Latent demand is expected to reach 4 million to 8 million kw, if part of the old oil-fired power plants are replaced by fuel cells.

(4) Priority items for practical use of fuel cells

① Tasks for R&D of on-site type (small- to medium-capacity dispersed installation type) fuel cells

R&D tasks for on-site type fuel cells which are expected to be put to practical use by about 1990 include: 1) R&D into areas related to combined heat and electric power generation, such as down-sizing of equipment, high efficiency, and enhanced operation characteristics; and 2) accumulation of experience and achievements in test running of systems by conducting field tests, and realizing low-cost systems. When using methanol as fuel, or when using hydrogen produced as a byproduct in factories, fuel cells may have no need for reforms at all, or may be able to use simplified reformers. Therefore, demonstration studies need to be made on such modes of system operation.

② Tasks for R&D of large-size (in excess of several tens of thousands of kilowatts) fuel cells

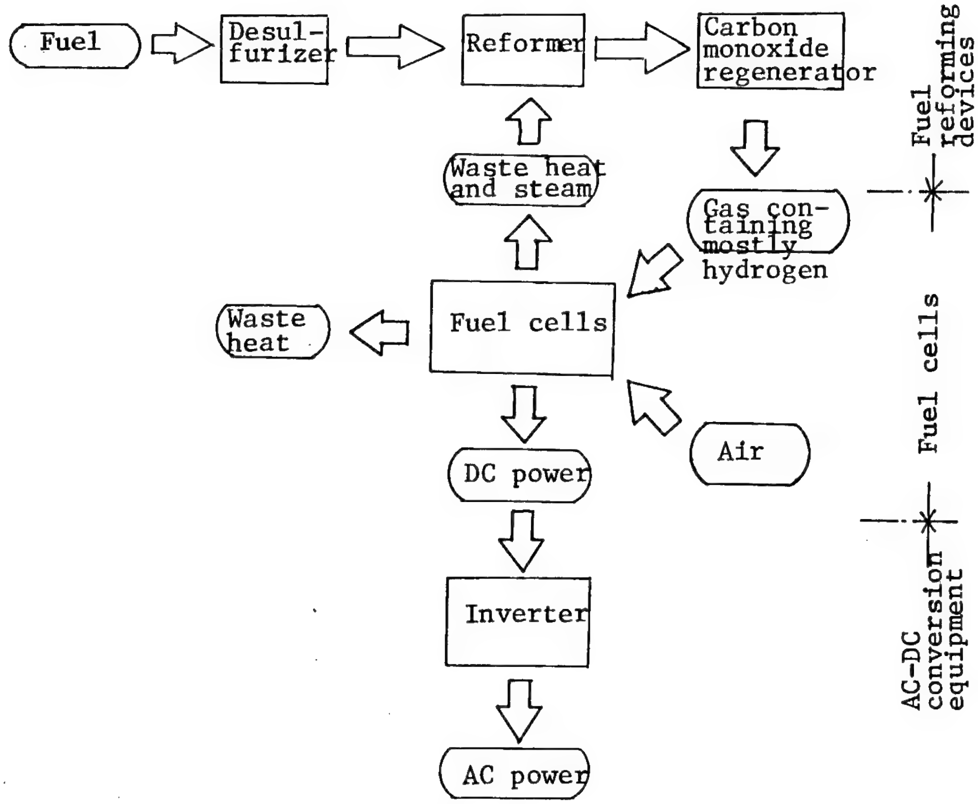
In medium-to-long-term research on large-scale fuel cells planned for practical use, technical tasks needing solutions are enhanced generating efficiency, long life of the system, low costs, down-sizing, and improved operations and maintenance. At this time, R&D plans need to be made while paying attention to the molten carbonate fuel cell, which is gathering attention as the next-generation technology.

-- ① Typical Fuel Cells

	Phosphoric acid type (first generation)	Molten carbonate type (second generation)	Solid electrolyte type (third generation)	Alkaline type
Fuel	Natural gas Methanol	Coal gas Natural gas Methanol	(Same as at left)	Hydrogen
Electrolyte (charge carrier)	Water solution of phosphoric acid (hydrogen ions)	Carbonate alkali salt (carbonate ions)	Zirconium oxide, etc. (Oxygen ions)	Water solution of potassium hydroxide
Electrode	Porous carbon (platinum catalyst)	Porous nickel, etc. (no platinum catalyst needed)	Nickel oxide, etc. (no catalyst needed)	Porous carbon (platinum, nickel, etc. as a catlyst)
Operating temperature	Up to 200°C	600-750°C	800-1,000°C	Up to 100°C
Combined thermal-electric efficiency	Above 40 percent	Above 45 percent	Above 50 percent	45 percent

Source: The Institute of Electrical Engineers of Japan, etc.

-- ② Conceptual Diagram of a Fuel Cell Power Plant



-- ③ Main Features of the Fuel Cell

Advantages

1. Since it produces electricity directly, it has a high generating efficiency.
2. The power generating efficiency of fuel cell plants is not affected by system size.
3. Total efficiency can be raised to about 80 percent through utilization of waste heat.
4. It poses few problems with respect to emissions of air pollutants and noise--environmentally benign.
5. A fuel cell at a reduced load is as efficient as at its rated load.
6. Fuel cell plants can be easily built of a modular structure, so they can be mass-produced in factories.

Disadvantages

1. A fuel cell's voltage fluctuates depending on changes in its electrical output.
2. A fuel cell generates a small output of low voltage.
3. A fuel cell produces direct current. (Can be an advantage.)

3. Power Generation Based on Wind Power

(1) Features

The characteristics of power generation based on wind power are 1) that it does not use any fuel, it taps natural wind, and 2) that it is subject to fluctuations in output, affected by changes in natural conditions, such as wind velocity.

(2) Status

① R&D

The status of R&D of wind power generation is as follows:

--A 100-kw pilot plant was built in 1981 on Miyakejima Island as part of the Sunshine Project, and it is being operated, interconnected with the power grid. As for MW-class plants, the concerned committee in the Industrial Technology Council, MITI, is studying the feasibility of introducing such systems in Japan.

--As for R&D by the private sector, test running of a 300-kw machine built by the electric power companies in Oki-erabujima Island is underway, interconnecting it with the utility power grid.

② Status of system introductions and costs

--Status of system introductions

- --Dozens of units, less than 10 kw in output, have so far been introduced into local governments, universities, and private industries for use as an independent in-house power source.
- --As for medium-scale systems, the electric power companies are planning to import commercial turbines from abroad for demonstration study.

--Current costs

The power generating cost of the 100-kw pilot plant built under the Sunshine Project is estimated to be around ¥210 per kwh, but the price is solely based on the construction cost of the experimental system.

(3) Cost efficiency of wind power turbines in the future, probable fields for introduction of wind power generation, and latent demand for wind power plants

① Prospects for cost reductions

When calculations are made based on the cost of the 100-kw plant built under the Sunshine Project while taking into account the advantages of system scaling up and of industrial skills in the course of mass-producing systems, the cost of a 500-kw unit, produced in large quantities, is

expected to drop to ¥90 per kwh, and that of a mass-produced 1,000-kw unit to ¥70 per kwh. However, the 100-kw plant, the very model used in the cost calculations, is the first experimental turbine Japan has produced for the development of large-size wind power generating systems. Consequently, the plant's cost is considered to be at a high level for it to be used as the basis for calculating the cost of commercially produced systems. A reevaluation of the costs is necessary by consulting with data at home and abroad.

② Probable fields for introduction of power generation based on wind power and latent demand for wind power plants

The following are considered to be fields where introduction of wind power systems is feasible. Latent demand for wind power electric generation is given.

--When wind turbines are to be used as an independent, small-scale power source in lighthouses, cottages, agriculture, and cattle farms, etc., judging from a survey of wind patterns across the nation, there appear to be many places where wind systems can be sited. User-demanded cost is difficult to calculate since it fluctuates widely depending on where a system is to be sited and how it is to be used, but latent demand is estimated at about a million units.

--Wind turbines of the several hundreds to MW class are expected to be introduced as alternatives to diesel generators in remote islands (user-demanded cost: ¥50-90 per kwh). Replacing an entire power supply system with wind power would entail large storage costs, so wind power would follow the way of a hybrid system, using a diesel generator and a wind turbine. Consequently, latent demand will probably be made up of part of the installed capacity of existing diesel generators on remote islands (about 400,000 kw).

(4) Priority items for system practicalization

① Tasks concerning systems' diffusion as independent electric power sources

Small-scale turbines of less than 100 kw in output are expected to find applications as independent power sources. But those enterprises planning to introduce such systems are considered to be small businesses, they will not be able to conduct a survey of wind patterns on their own. Therefore, surveys are needed of the wind patterns in promising areas in advance. Prior feasibility studies are needed, and standardization of design needs to be established according to the system's use (for use in agriculture, or in leisure facilities).

② Tasks concerning a wind system's use in combination with a diesel generator in remote islands

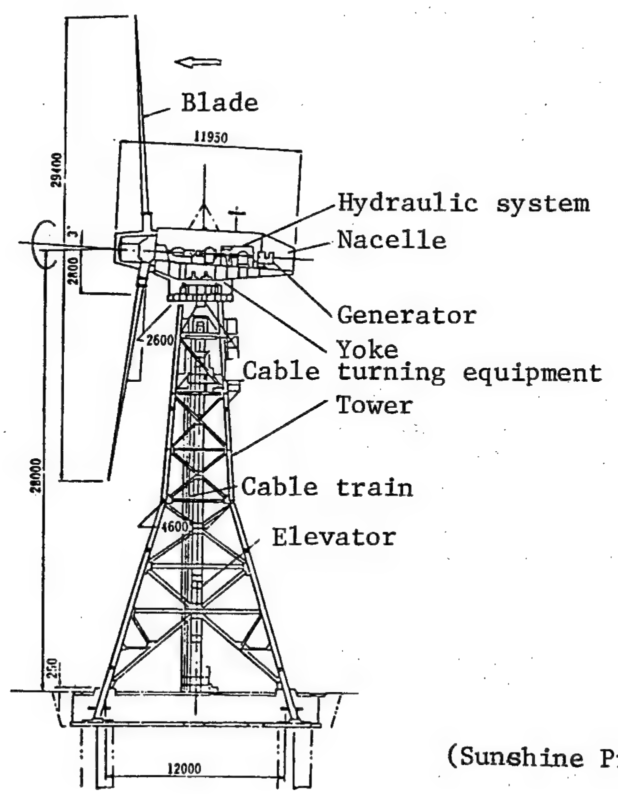
Where wind power systems are to be introduced for electric power generation in combination with diesel generators on remote islands, a nationwide

centralized survey of the wind patterns in candidate areas for the installation of such systems is needed to see if costs can be brought down through standardization and to see if units can be produced in large numbers. Based on the results of the survey and breakthroughs in technical development, future possible introduction of prototypes for demonstration operation will become a matter for study.

-- ① Types of Windmills

- Windmill
  - Horizontal-axis windmill
    - Netherlands type
    - Propeller type
    - Multivane type
    - Sail wing type
  - Vertical-axis windmill
    - Paddle type
    - "Sabonieus" type
    - Gyro-mill type
    - Darrieus type
    - Edge mill type

-- ② Configuration of Propeller-Type Wind Power Generating System



(Sunshine Project)

-- ③ Major Features of Power Generation Based on Wind Power

Advantages

1. Wind power is clean and renewable.
2. Wind power generation does not need any fuel.
3. Wind power generation causes no air pollution.
4. Wind power exists in large quantities.

Disadvantages

1. Output is subject to fluctuations by the hour of day, depending on weather conditions.
2. Wind power has a low density of energy.
3. Wind power generation is costlier at present.

4. Solar Systems

(1) Features

The features of solar systems are 1) that they do not need any fuel since they use solar energy that exists in nature in unlimited quantities. Yet they do not pose any load on the environment, and 2) that they do not need any heat storage facility since they are responsive to demands for heat.

(2) Status

① Status of R&D

R&D on consumer solar system technology was undertaken in the FY 1974-1981 period under the Sunshine Project and is now at the stage of practical application. R&D of industrial solar systems (cascading heat process, fixed heat process, long-term heat storage) has continued since FY 1980.

② Status of product introduction and costs

--Status of product introduction

About 230,000 solar systems for consumer use and about 4.9 million solar devices for heating water for household use have so far been installed, but industrial solar systems have yet to reach the stage of widepsread application.

--Costs

--Installed costs

The installed cost of a solar system, which is the total of the system costs (costs of solar arrays, heat storage tank and other equipment) and installation costs, are about ¥170,000 per square meter on average

for household systems for hot water supply. That for a solar system for industrial processes (process heat) is about ¥270,000 per square meter on average.

--The time required for recovering the cost of equipment investment

On the basis of costs of city gas supply, the length of time required for recovering the cost of investment into a system is 8-10 years for household systems and 8-11 years for large-scale systems, provided the current subsidy system continues to exist.

(3) Cost effectiveness in the future, probable fields for introduction, and latent demand

① Prospects for cost reductions

Shortening the length of time required for recovering the cost of investment into a system by 2 to 3 years is considered possible by bringing down the costs of manufacturing such systems through 1) standardization of systems, 2) mass production, and 3) process automation.

② Possible fields for introduction and latent demand

Fields where introduction of solar systems is considered feasible with latent demand for solar systems in each of those fields include the following.

--With about 35 million family homes and apartment houses in Japan, latent demand for household solar systems is considered to be in the 17-20 million range. This figure considers such factors as the characteristics of the areas where they are sited, structural requirements, and availability or nonavailability of hot water supplying systems.

--With about 150,000 public facilities in Japan, latent demand for solar systems is considered to be in the 80,000 to 100,000 units range. This considers conditions of the areas where they are sited, and sunshine conditions.

--As for solar systems for business use, about 900,000 to 1 million, out of 2.8 million office buildings and stores in Japan are considered to be possible purchasers of such systems. Factors here are the conditions in which they are sited, and the availability of space for their installation.

--Latent demand for industrial solar systems is considered to be in the 1.2 to 1.35 million range after considering such factors as sunshine conditions, siting conditions, etc. in the case of demand for low-temperature heat, and such factors as constraints of installation space, siting conditions, etc., in the case of demand for relatively high-temperature heat.

--Furthermore, solar systems may be introduced for such uses as seawater desalination.

(4) Priority items for system practicalization

① Tasks needing solutions to realize expanded use of consumer solar systems (for use in housing, offices, stores, etc.)

At present, the length of time required for recovering the cost of investment into a consumer solar system is 8 years. If consumer solar systems are to find an expanded use in the future, the period for capital recovery needs to be shortened to less than 5 years, the yardstick considered standard to trigger widespread use. To that end, the following measures may be effective.

--Approach from cost aspects

--Technical development of low-cost heat collectors, high-performance heat storage tanks, and multifunctional heat collectors.

--Development of new demand fields, such as for use in snow-melting, and for use as a heat-storage type floor-heating system.

--Bringing engineering costs down through introduction of a roofing structure in newly built homes in which the roof and solar system are built as a monolithic structure.

--Consolidating manufacture of components through adoption of the OEM system in their production.

--Approach from system aspects

--Expanded use of certification and approval systems.

--Tax incentives to those installing solar systems.

--Other approaches

Improved engineering techniques in such respects as adaptation to the area community, harmony with the building, beauty of the town and streets, as well as an improved servicing system.

② Tasks pertaining to the development and introduction of industrial systems

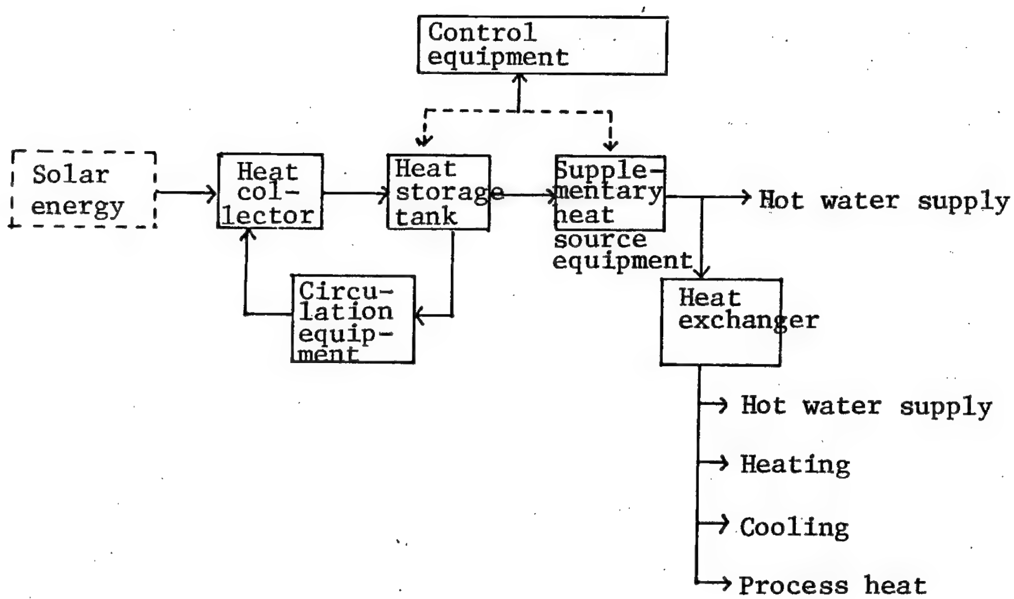
From the point of view of utilizing the accumulation of technology gained in the Sunshine Project and of utilizing the vitality of private industry, it is appropriate to introduce some form of competition in R&D aimed at development of low-cost, high-efficiency heat collectors and heat storage devices.

The most effective way to line up potential customers in the initial phase before a system can have wide diffusion is to enlighten the customer by field testing the machine. It is considered necessary to lighten the burden of the user planning introduction of a system which is still in its early diffusion stage by establishing a leasing arrangement where machines can be had on a leasing contract for test running.

-- ① Classifying Solar Systems by Use

- Hot water supply system
  - Natural circulation system
  - Forced circulation system
    - Direct heating system
    - Indirect heating system
- Hot water supply/heating system
  - Water as a heat medium system
  - Air as a heat medium system
- Hot water supply/(cooling) heating system
  - Heat pump system
- Cooling/heating and hot water supply system
  - Absorptive type cooling and heating system
  - Ranking cycle type cooling and heating system
- Process heat system

-- ② Basic Configuration of a Solar System



-- ③ Comparing Industrial and Household Solar Systems as to Differences in Demanded Features

	Industrial	Household
Scale	Industrial solar systems come in various scales, depending on the temperature required and use, but they have an effective heat-collecting area much larger than that for household solar system.	Average household solar systems have an effective heat-collecting area of around 4 square meters.
Temperature required	In some applications, e.g., preheating a water supply before it is pumped to the boiler, all that is demanded of industrial solar systems is to raise the temperature of the water to some extent. But if industrial solar systems are to be used for generating heat for industry, they should be capable of producing heat up to about 200°C.	The majority of household solar systems are used for hot water supply and heating, so they need only produce hot water of 40 to 60°C. Even when a household solar system is to be used as a heat source for an absorption type cooling system, it needs only to produce hot water of 80 to 90°C.
Characteristics in use	Depending on the application of industrial solar systems, in most cases they are used as a heat source for machinery systems that exert a constant load for a certain length of time. Therefore, industrial solar systems must provide a large-scale heat storage tank or a supplementary heat source so that they can cope with the demand for a constant load.	Where household solar systems are used as a heat source for running air-conditioning systems, they need a heat storage tank or a supplementary heat source, if the home appliances are to be operated on a stable basis, to provide a constant amount of heat. But in the majority of solar systems' applications in homes, providing hot water, the demand for loads is not constant.
Economic effectiveness	Where an industrial solar system is being used in a plant, the solar system itself is designed from the beginning as a subsystem for the generation of heat for production processes in the plant. Therefore, the solar system needs to depreciate in the same span of time as	Where a solar system is to be installed in a family house, the time for the system's depreciation may be extended up to the life of the house itself.

[continued]

	Industrial	Household
[continued]	that for the entire manufacturing equipment and facility. The life of the collectors installed outside the building is an exception to this rule. The life of the production equipment and facility is determined by law. In a growth industry, the life cycle of a product is short, which necessitates that the equipment and facility depreciate in a shorter period of time. It is desirable that solar systems depreciate within 5 years.	

5. Methanol for Fuel

(1) Features

When used as a fuel, methanol has the following features:

① A liquid, at normal temperature it is colorless and mixes with water at any mixture rate.

② It has a calorie of about 4,500 kcal per kilogram, about one-half of oil.

③ Since it acts corrosively against metals, special materials need to be used at every stage of storage, transportation, or utilization.

(2) Status

① R&D

--Manufacturing technology

The technology of producing methanol from natural gas and oil (naphtha, residue oils) has been established. Three-fourths of the output of industrial methanol in the world comes from natural gas and the remaining one-fourth from oil. No coal-based methanol-manufacturing technology that is competitive with natural gas- or oil-based technology, at their current price, has been developed.

--Use of methanol as fuel for automobiles

--Technology to utilize low-density fuel mixtures

As part of its R&D of new fuel oil, MITI, since FY 1980, has been studying the effects of methanol-oil mixed fuel, which has varying ratios of methanol content running up to 20 percent, to run automobiles, for gas pumps, etc.

At present, research continues on a 3 percent methanol and 2 percent solvent fuel. The fuel's effect on the life of present model cars has yet to be evaluated.

--Technology to utilize high-density and neat fuel

Development of an Otto-cycle engine that burns a neat fuel (100 percent methanol) has continued since FY 1980 by private organizations under the "Subsidy system for promoting development and practicalization of oil alternative energy technology."

The major automobile makers are at an advanced stage in R&D of Otto-cycle engine cars. Research is still at a basic stage in the case of diesel-cycle engines.

--Technology to utilize methanol as a fuel for thermal power plants

Under the MITI project, "Studies for demonstrating and testing the practicality of converting fuel in oil-fired power plants to methanol, etc.," tests have been conducted since FY 1981 1) to demonstrate the safety of large-scale use of methanol on the environment, and 2) to evaluate the economies of methanol-fired power generation systems.

② Costs and status of introduction

--Status of introduction

Low-density methanol-oil mixed fuels (containing 3 to 5 percent methanol and about an equal amount of solvent) have been used in some automobiles in the United States and West Germany.

--Costs

As of FY 1984, the import price of methanol was about ¥36 per kg, while the cost of the alcohol on delivery at the methanol plant was about ¥57 per kg. Given the above-mentioned costs of methanol and its calories, cost calculations of the fuel, relative to the costs of existing fuels, including oil-based fuels, need to be conducted with a great degree of flexibility. The following estimates are considered appropriate.

--Low-density fuel mixture (95 percent gasoline, 3 percent methanol, and percent solvent) costs about as much as gasoline.

--Costs of high-density fuel mixtures (85-95 percent methanol mixed with hydrocarbon oils like gasoline) and neat fuels differ depending on tax levies. With no taxes levied on methanol at present, they cost about as much as diesel oil. In case they are to be levied with taxes about as much as gasoline.

--When methanol is to be used for firing thermal power plants, it is more expensive than LNG and heavy oil in terms of the cost of unit power produced.

The first two cost estimates, however, do not take into account what should be included in the cost evaluation of methanol as fuel when it is to be put to practical use, such as the additional cost needed to establish the fuel distribution system, and the cost of remodeling cars.

(3) Economies of methanol fuel in the future, probable fields considered fit for introduction of methanol, amounts of methanol introduced

① Prospects for cost reductions

--The prevailing view holds that the cost of methanol will follow a slightly upward spiraling curve. It is also anticipated that in case demand expands in the future for methanol as fuel, the supply and demand situation surrounding the fuel will tighten, pushing up its price. Some calculations, however, hold that importation of low-cost methanol is possible, provided necesary conditions are met, such as cheap raw material costs, and a well-prepared infrastructure.

--The supply and demand situation for oil, on the other hand, is anticipated to shift on a bearish trend for some time to come. However, oil prices could go up momentarily, depending on changes in the Mideast situation, and the prevailing view is that within the 1990's, oil prices will again spiral because of a tightened supply and demand situation.

② Candidate areas for introduction, and latent demand

Fields considered fit for introduction of methanol and estimates of the latent demand in those fields are as follows:

--Methanol as fuel for automobiles

--Low-density mixture

As for low-density fuel mixtures which have gasoline mixed with about 3 percent methanol and 2 percent complementary solvents (such as butanol), there is no specific need for promoting their introduction, nor are there any economic advantages, so their introduction in large quantities is not likely. Although methanol's long-term effect on

cars has yet to be evaluated, in a short-term perspective, the fuel is applicable to the current generation of automobiles without much remodeling work on them. Hence, there exists the chance that the fuel may be marketed by some gas pumps. (Were methanol to be used by about 10 percent of the registered passenger cars, trucks, and buses, annual demand for the fuel would reach about 70,000 tons.)

--High-density mixture and neat fuel

High-density fuel mixtures and neat fuels cannot be used, in their original form, as fuel for the current generation of cars, and the technology is now at the stage of engine development. The cost-effectiveness of these fuels is determined by their costs relative to oil prices, so forecasting the day when they will begin to be used or the fields considered fit for their application is difficult. (Were these types of fuels to be used by about 10 percent of the otto-type passenger cars, trucks, and buses on the streets, annual demand for methanol would reach about 4 million tons.) But a limit is supposed as to how far methanol will go as a fuel, affected by various economic and time constraints as well as the government's energy policy and its policy judgments with respect to the related industry. These factors include how fast supplies of methanol will expand as its price competitiveness relative to oil changes, how establishment of a nationwide distribution system will progress, or how far introduction of methanol ought to go from the point of view of optimizing the nation's supply system of fuels for vehicles.

--Methanol for thermal power generation

Provided that its large-scale use will have no harm on the environment, that it will be competitive with oil in price, and that its supplies can be had on a secure basis, methanol has great potential as an alternative fuel in thermal power generation.

More than 10 million kw of the thermal power generation capacity is expected to be replaced by some other power sources by the year 2000. It is difficult to say at this point how much of that replacement will come from methanol. (To replace a 300,000-kw capacity with methanol-fired power generation, annual consumption of the fuel would reach some 1 million tons.)

(4) Priority items for realization of methanol fuel

① Securing long-term supplies of fuel on a secure basis

If methanol is to be used as fuel, the expected current world capacity in methanol production would not be able to meet demand. Therefore, if supplies of methanol are to be had at low cost and on a secure basis, Japan will have to explore on its own new sources of methanol supply. Since prospects are not necessarily clear for methanol's introduction as fuel at this stage, the problems of how to spread thin the risks of capital investment needed for development and importation of the resource and how to

diversify the supply sources of the fuel need to be studied from a long-term perspective, including the possibility of development and importation through international cooperation.

② Tasks relating to methanol's use as fuel for cars

--For methanol, particularly high-density methanol-gasoline mixtures, or neat fuels, to be introduced smoothly as fuel for automobiles, vast sums of money need to be invested for R&D, and into facilities and equipment, such as for development of exclusive cars, construction of new supply and distribution facilities, and in some cases development and importation of methanol. In order to save corporations from having a muddled car technology development schedule or from incurring losses on their corporate balance sheet by making unnecessary capital investment, a well-planned schedule, and clear prospects for introduction of methanol in the future should be presented.

--Presentation of desirable mode of use

Pursuing simultaneously the two fuel utilization modes, the high-density fuel mixture and neat fuel, which both presume use of cars specially built for the fuel, may force the industry into an overlapping of investment into car technology R&D and into the establishment of fuel distribution facilities and equipment. According to studies made so far, neat fuel has more problems than the high-density fuel mixture. These include:

--When neat fuel is to be used for firing Otto-type engines, filling up a car, it is feared, may involve a two-step procedure. This would not only increase the burden on the fuel's consumer but could push the cost of cars specially built for the fuel far above that of cars geared to high-density methanol-gasoline mixed fuel. This is because the fuel system of a neat fuel-oriented car may need to be built up of two separate subsystems.

--Since discriminating between a pure neat fuel and a fuel adulterated with a large quantity of water is difficult, there is always the possibility of unethical behavior.

--Since neat fuel burns without any visible flame, is odorless, and explodes more readily than other fuels, it poses safety problems in the distribution phase and in auto accidents.

When the problems associated with neat fuel are taken into account, together with the fact that for the same reasons the trend in methanol fuel experiments abroad is away from neat fuel and toward high-density methanol-gasoline mixtures, the high-density fuel mixture is more desirable than neat fuel. The government, for its part, is required to conduct experiments with the emphasis placed on finding out what problems exist with respect to distribution and safety of methanol fuel. The government should come out with a final judgment as soon as possible.

--Measures to guarantee quality, such as fuel specifications

As for low-density mixed fuel with up to 3 percent methanol in content, its use in the current generation of cars poses, it is understood, no problem, provided the fuel is mixed with appropriate compatible solvents, from a short-term point of view. But the fuel's long-term effect on car life has yet to be evaluated, and the market may witness a coexistence of one type of vehicle compatible with low-density mixed fuel, and another type of car not compatible. Some measure will have to be implemented to clearly differentiate gasoline from low-density mixed fuel so that the consumer can correctly choose the type of fuel he really wants. Furthermore, how to prevent the circulation of low-density mixed fuel diluted with water is a problem throughout the entire length of the distribution system, from the refiner to the remote outlet. In this context alone, guaranteeing proper quality of the fuel is an important issue.

--When methanol is to be used as fuel for automobiles, it is desirable that the fuel be in the form of high-density mixed fuel. For efficient development of a methanol-only car, the prerequisite is to come up with the properties of the fuel for the car in advance. Therefore, the government is requested to establish as soon as possible the desirable specifications of the fuel as to the ratio of methanol content in the mixed fuel, the ratio of additives like gasoline, and to start as soon as possible studies on a method of informing the consumer about the kind of fuel he is buying. Some countermeasures will also have to be taken against the fuel from being adulterated with water in the distribution stage.

--If methanol fuel is to be introduced in the future, coming up with fuel specifications which will contribute to an efficient development of methanol-only Otto-cycle engine cars, is but one of the problems. There are many tasks, such as the life of distribution facilities, deterioration of fuel, safety and prevention of fire in the distribution stage, and impact of the fuel on the environment. The government is therefore required to conduct necessary experiments to solve these problems. At this time, government programs for research and study need to follow a program and to be in close coordination with related industry in order to prevent unnecessary overlapping of research efforts between government and industry.

As for methanol fuel-only Otto-cycle engine cars, many basic technologies still remain, common to all types of cars, that need solutions. The government is requested to make further efforts for R&D.

--Promotionary policies such as tax incentives

--Taxation system

In the case of existing fuels for vehicles, such as gasoline, they at present are levied with various taxes, i.e., the gasoline tax, which are the source of funds for road construction. In addition, they have the petroleum tax which is imposed from the point of view of promoting

the nation's energy policy. In considering introduction of methanol fuel, how to treat these energy policy-related taxes and road construction-related taxes with respect to methanol fuel is a matter requiring further study.

--The way the fuel supply system should be

If low-density mixed fuel were to be introduced, the fuel would basically be marketed through existing distribution and supply channels for gasoline. In the case of high-density mixed fuel, a new distribution and supply network will have to be established. In building up such a network of supply and distribution, consideration would have to be given to minimizing the socioeconomic costs of such endeavors by making the most of the existing network of gas pumps, while paying attention to such elements as the convenience of consumers, quality of the product and product safety. We believe it is the time for the related industries to start research for the most desirable form of supply and distribution system by extending cooperation to various government experiments planned for the immediate future.

③ Tasks relating to methanol's use as fuel for thermal power generation

--Study of environmental safety

When methanol is to be used as fuel for thermal power generation, the fuel will have to be kept in storage and be combusted in large amounts at a single facility. It is feared that formaldehyde contained in methanol and its combustion gas may have some adverse effect on the surrounding environment. Therefore, while continuing with the required experiments to confirm that burning of methanol poses no problems, all necessary precautions would also have to be in place in advance.

--Development of high-efficiency power generation technology

Even with current power generation technology, methanol can be used not only as fuel for combined-cycle power generation and in gas turbines, but also can be introduced as an alternative fuel relatively easily into oil-fired power plants with some modifications of the facilities. With these power generation technologies, however, the use of methanol results in reduced power generation efficiencies, so power generation technology of much higher efficiency needs to be developed.

Methanol-reforming type gas turbine technology has the potential to raise the total efficiency of power generation if waste heat from the gas turbine is effectively utilized by taking advantage of methanol's feature that it is amenable to reforming at relatively low temperatures. In promoting development of methanol utilization technology, whose pace of development is closely related to the movement of oil prices, we think it is necessary to conduct research into the technology's basic elements, while paying attention to oil prices.

Problems Associated With Methanol's Use as Fuel in Automobiles (Classified by Mode of Use)

		Low-density mixture (up to about 3 percent)	Medium-density mixture (about 3 to 55 percent)	High-density mixture (about 55 percent, below 100 percent)	Neat (100 percent)
Technical problems	Compatibility with autos	o Can be used in the current generation of vehicles o Is a bit inferior to gasoline in quality (in high-temperature operation characteristics, etc.). o The effects of long-term use of methanol on the life of car materials is unknown (this gives rise to the problem of maker's product warranty). o Is being used in some cars in the United States and West Germany (in the United States, the opinion is divided). o Cannot be used in diesel engines.	o Is not appropriate for use in the current generation of cars from the aspect of their operation characteristics (the limits are about up to 5 percent mixed fuels). o No study has yet been made on cars designed exclusively for combustion of mixed fuels. o Once specifications on the fuel have been established, development of an exclusive car for the fuel is considered feasible, but about as much of an investment into R&D as that for development of an exclusive car powered by a high-density mixed fuel or neat fuel would be needed. o Gasoline unlawfully adulterated with this mixed fuel may be marketed to unwary drivers, thus risking the fuel's introduction in the current generation of cars. o West Germany has tested the fuel using a fleet of exclusive M-15 cars. The tests were successful but West Germany shelved plans for the fuel's practicalization because it has few advantages.	o Major makers are in an advanced stage of R&D. o Before the fuel can be put to practical use, the effect of the fuel on the life of materials, exclusive lubricants, etc., needs to be thoroughly studied and evaluated. o The fuel is the principal target for fleet testing in the United States and West Germany. o R&D for the fuel's use in diesel cars (heavy-duty cars) is still in the basic research stage.	o The situation is the same as that for the high-density mixed fuel. o The situation is the same as that for the high-density mixed fuel. o The fuel is partially undergoing fleet testing in the United States and Sweden. o The situation is the same as that for the high-density mixed fuel (a few buses are undergoing fleet testing in the United States and West Germany).
	Fuel characteristics	o An increase in the octane rating (the feature has no special advantages in Japan because gasoline in the country contains no lead). o Deterioration in vaporization characteristics (leading to worsened driving characteristics at high temperatures such as vapor lock).	o Depending on the ratio of methanol content in a mixed fuel, the fuel may be able to increase a car's fuel efficiency by the adoption of a high compression rate, but it is inferior to high density or neat fuel. o The fuel is the same as the low-density mixed fuel in terms of worsened vaporization characteristics, and of the danger of water absorption and phase separation.	o Increased fuel efficiency due to the adoption of a high compression ratio. o Small calorific value (shorter traveling distance, or needing a larger fuel tank). o Low cetane number (a diesel engine may require a supplementary ignition system).	o Same as at left. o Same as at left. o Same as at left. o An Otto-type engine needs to be filled up with two types of fuel, increasing the driver's troubles. o The fuel cannot be distinguished from chemical methanol (leading to the possibility of chemical

[continued]

[Continuation of Table]

		Low-density mixture (up to about 3 percent)	Medium-density mixture (about 3 to 55 percent)	High-density mixture (about 55 percent, below 100 percent)	Neat (100 percent)
		[continuation] o When not properly controlled, the fuel may lead to water absorption and phase separation.			methanol being sold as fuel methanol or of chemical methanol being erroneously used as fuel. o Distinguishing a neat fuel mixed with a large quantify of water from a genuine fuel is difficult, so there is the danger of "adulterating."
Environmental safety	Exhaust gas characteristics	o Being about as noxious as gasoline, the fuel could pass current standards on exhaust gas (emissions of CO decrease a bit, while those of NOx and aldehyde increase a little).	o When used in the current generation of cars, the fuel would greatly aggravate the exhaust gas situation (emissions of hydrocarbons and NOx would exceed emission standards). o Studies have yet to be made on exclusive cars, but emissions of aldehyde and unburnt methanol need to be made.	o The effects of aldehyde and unburnt methanol (especially at the time of ignition at low temperature need to be evaluated). o If the fuel were to be used in diesel engines, this would be effective in solving the problems of smoke and NOx.	o Same as at left. o Same as at left.
	Safety	o Is about as safe as gasoline	o A thorough evaluation is yet to be had but the safety factor is at the same levels as those for the low-density and high-density fuels, depending on the ratio of methanol mixed.	o Experiments are required to confirm the problems mentioned in the neat column but some forecasts say they are soluble (the same view is also held in the United States and West Germany).	o The fuel burns invisibly, emits no odor, and explodes readily, posing safety problems in distribution and in case of an auto accident. o By law, methanol is placed on the list of poisons and explosives (requiring written papers and seals in the marketing of the product).
Cost effectiveness	Fuel	o Is about as cost efficient as gasoline	o Since there have been no experiments nor evaluation, evaluating the fuel's economies is impossible.	o If it is not taxed, the fuel will cost about as much as diesel oil. If the fuel is levied with a tax equivalent, calorie-wise, to the gasoline tax, it will lose its competitiveness with diesel oil and will cost about as much as gasoline.	o Same as at left.
	Others	o Can be used in the current generation of cars, and present distribution networks can also be used.	o Improvements need to be made on distribution networks. o Because of the necessity of establishing the distribution network and of developing exclusive cars, fuel will push up the overall cost.	o Same as at left. o Same as at left.	o Because of the two separate fuel systems needed, the autos powered by this fuel may cost much more than those for high-density fuels (in the case of Otto-type engines).

IV. Development of Future Policies

In promoting policies for the development and introduction of new energy sources, we consider, based on the analyses we have done, that the following points should be kept in mind.

1. R&D of New Energy Sources, Accompanied by Their Accelerated Introduction

(1) R&D of a new energy source is to be promoted systematically, and similarly the achievements in the technology's performance and cost are to be gained step by step. In the case of the new energy sources taken up for study this time, in particular, there always exists a latent demand for the energy, the scale of which is commensurate to each of the energy's cost levels. If development and introduction of the new energy sources are to be promoted on a realistic and steady basis, what is important is to find a market for the technology, a market that can absorb the technology's cost, at each stage of the technology's development process. Simultaneously, we must pursue technological development toward the technology's long-term objective. At this time, from the point of view of promoting diffusion of the technology on a secure basis, attention needs to be paid not only to the energy's cost but also to its acceptability by the society in terms of safety and environmental safety.

(2) Studies need to be made on the following points in promoting diffusion of the new energy sources

① How to transfer the fruits of the R&D activities conducted with state subsidies to the private sector (to be concrete, subsidies to demonstration studies by the private companies, flexibilities in the handling of the issue of to whom the patent right belongs).

② How to give the marginal user an incentive to adopt new energy at each stage of the technology's development (availability of a leasing system, granting of low-cost money, taxes).

③ How to enlighten people about the importance of new energy sources, leaving the doors of new energy plants open for the general public, education through school textbooks, enlightenment activity).

2. The Role of Technical Development and Industry's Familiarity With New Energy Sources in Reducing Their Costs

(1) Depending on their specific features, the candidate fields for the introduction of the new energy sources under study can be anticipated, thus enabling each of the new energy sources to establish an estimate on cost where it will be able to compete with existing energy sources. Toward the attainment of this goal, technical development needs to be promoted steadily and from a long-term perspective. At this time, money and talent should be emphatically diverted for R&D of element technologies particularly needing technical breakthroughs.

(2) On the other hand, latent demand for a new energy source reveals itself at each stage of the technology's developmental course. The resulting expansion in the demand base will lead to improvements in manufacturing technology (lowered off-specification rate, automation of manufacturing lines) and to benefits of mass production. Such industrial familiarity with the technology will further contribute to bringing the cost of the new energy down. The new energy-related machinery and equipment differ from ordinary tools in that they are used to produce a final demand product of uniform quality, energy. With no difference in the final products they manufacture, new energy-related machinery and equipment are forced to engage in fierce cost competition from the initial stage. Consequently, a system is needed in which emerging demand for new energy sources will be effectively reflected as an increased industry familiarity with the manufacturing technology and processes of new energy-related machinery and equipment, thus contributing to bringing their costs down. (Peripheral equipment other than modules in solar light power generation, fuel cells, and wind power generation.)

3. Promotion of International Cooperation in the Field of New Energy

(1) The meaning of international cooperation

① A review of world demand for oil shows that with their economies growing, the demand for oil in the developing countries will expand greatly (IEA forecast, etc.). An increase in oil imports by non-oil-producing developing countries would not only aggravate the international balance of payments in those countries but might squeeze the energy supply situation of the world. Therefore, developing domestic energy sources, especially renewable energy, is a priority task for non-oil-producing developing countries. Consumption of oil is expected also to increase in oil-producing countries, such as OPEC, as socioeconomic development there progresses. Meeting part of the increased demand for energy with the development and introduction of non-oil energy sources such as solar energy would also contribute to easing the squeeze on world energy supply and demand.

② It is desired that the advanced countries, including Japan, extend cooperation to the developing countries in their efforts for introduction of new energy, either through multilateral or bilateral channels. Being a consumer of a large amount of energy and a technically advanced country, Japan should show a positive attitude toward technical cooperation.

③ With the supply and demand for oil slackening, the environment surrounding technical development of the new energy sources is becoming ever more severe, and this situation is the same for all countries of the world. If countries of the world cooperate in R&D in the fields where they are strong, this would contribute greatly to the development of new energy technology. Japan should actively participate in joint research projects among the advanced countries so that its technical development would be promoted more efficiently.

(2) How to promote cooperation with the developing countries

In promoting development of renewable energy sources in the developing countries, it is often the case that those countries either have a limited amount of the basic data on those energy sources (such as available amount), or they are lacking the ability to conduct such resource surveys. It is necessary to extend cooperation in these fields. In order to help research organizations in the developing countries enhance their technical development capabilities, international cooperative projects taking advantage of R&D entities in Japan should be further beefed up. Furthermore, in order to help private companies in the developing countries in their efforts to elevate technical capabilities, Japan should actively set up joint ventures in the host countries.

(3) How to promote cooperation with the advanced countries

First, our country's research cooperation with other advanced countries could be found in joint research in sophisticated yet basic fields seeking breakthroughs in long-term themes such as element technologies. For our country's joint research with other countries to be promoted efficiently, we would be required to set up a research system under which the capability of the R&D entity could be made the most of at each stage of the technology's development. The second way of promoting research cooperation could take the form of exchanging demonstration machines to conduct joint demonstration studies (field tests, monitoring, evaluation). As to whether such research cooperation among technically advanced countries should take the form of bilateral cooperation or multilateral cooperation, the issue will have to be evaluated and judged on a case by case basis, depending on the individual technical development task involved.

4. How to bring into harmony utilization of the market mechanism with the promotional system of subsidies

(1) Competition with existing energy sources on the market

Unless they can ultimately compete with existing energy sources in the market, new energy sources will never be able to hold their own. The new energy sources under study may be able to compete with existing energy sources in the market on a medium- and long-term basis. Characteristic features about these new energy sources, however, are that their cost goes down step by step in keeping with the advance in their technological development and with the degree of the industry's familiarity with the technology, and that demand for them emerges, in most cases, in response to cost reductions. For this reason, some temporary policy measures aimed at facilitating acceptance by the market of new energy sources need to be implemented.

The issues of when a new energy technology will become eligible for subsidies, the scope of such subsidies, and their content should be judged as occasion demands, to reflect the technology's state of development and its market penetration. A balance should exist between the subsidy system for new energy and that for existing energy sources.

(2) The way the subsidy systems should be

For assisting introduction of a new energy source effectively and efficiently, subsidies need to be given at an early stage of the technology's development when latent demand begins to emerge for the energy in the market. In determining the contents of a subsidy system for a new energy source, prior evaluations need to be had as to 1) who should be given priority access to the subsidiary system, the production side or the demand side, and 2) which, of the various means of providing subsidies including financial assistance and tax credits, is the best, by taking into account the state of the technology's development at the initial stage of the energy's introduction and the state of its introduction.

5. Reexamining This Vision at Regular Intervals

Not limited to the new energy sources under study by NEIRC, R&D of new energy sources in general is advancing rapidly. Depending on what changes may occur on the energy front, the premises on which this vision is based may be upset. Therefore, instead of committing our country's choices rigidly to the new energy sources under study, we should regularly reexamine at intervals of several years what other options may be open to us. We must take into account not only future progress in research into new energy as a whole and the changing supply and demand situation for energy, but also long-term energy requirements in the years beyond the year 2000.

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CSO: 4306/2506 END